THE ENGINEERING REVIEW.

Edited by
C. EDGAR ALLEN.

Vol. XII. JUNE, 1905. No. 6. (New Series.)

Efficiency of Injectors and their Comparison with Pumps.

By R. FLEISCHBERGER.

BEFORE going into the above subject, it will perhaps be well to deal to some extent with the theory of the injector for the benefit of those not acquainted with its action.

It is a well-known fact that all the steam used for working this apparatus returns to the boiler along with the feed, this being accomplished in the following manner:—

In Fig. 1, which represents diagrammatically the section through the cones of an injector, the steam issues from nozzle A, and by the inducing action of the jet receives at B, the water to be fed into boiler, whence it is carried through the combining cone C by the steam. Whilst passing through this cone, a complete or nearly complete condensation of the steam takes place, its latent and a part of its sensible heat being added to the temperature of the water, which is accordingly increased. The jet of hot water, thus established, enters the feed pipe to the boiler through the throat D and the delivery cone E. The result so obtained appears to be paradoxical; but if all facts are carefully considered it will be seen that it can easily be explained by the well-known principle of the "conversion of energy."

The equation $v = \sqrt{2gh}$ holds good for all non-elastic fluids issuing from orifices under pressure; and, as $h = \frac{P}{\delta}$ (where δ density in lbs. per cubic foot, and P = pressure in lbs. per square foot), the velocity varies inversely as $\sqrt{\delta}$ for fluids of different density at the same pressure.

However, as steam is a gas, this equation is not applicable to its flow, but it serves well to show that its velocity must be very much higher than that of water at the same pressure, its density being considerably less. As a matter of fact, the velocity of steam varies from 1,000 to 3,000 ft. per second for about the same range of

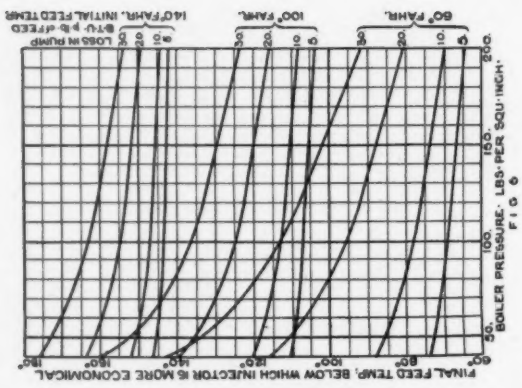
60° FAHR.
100° FAHR.
140° FAHR. INITIAL FEED TEMP.
LOSS IN PUMP B·T·U. p.lb. of FEED
BOILER PRESSURE - LBS. PER SQU. INCH.
FINAL FEED TEMP. BELOW WHICH INJECTOR IS MORE ECONOMICAL.

FIG 6

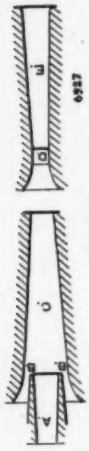

FIG 1

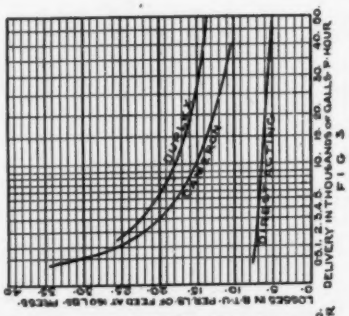

FIG 2

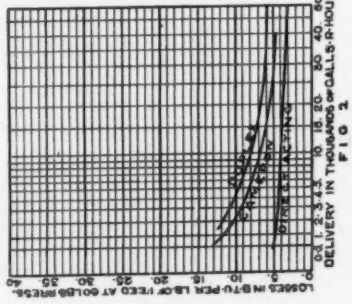

FIG 3

INJECTORS V. PUMPS.

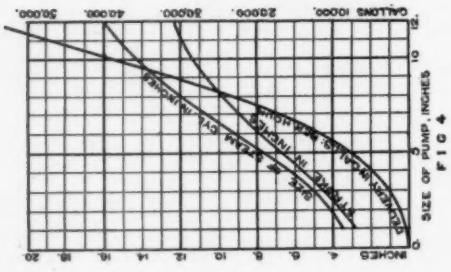

FIG 4

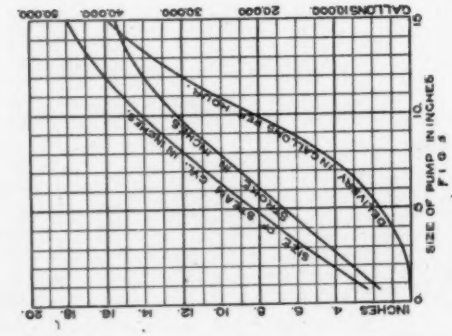

FIG 5

pressure, within which the flow of water does not attain a higher velocity than about 180 feet per second. Therefore, if we condense steam whilst issuing from an orifice or nozzle at this high velocity, we obtain a jet of water retaining the original velocity of the steam.

Although the principle of the injector is dependent upon this fact, it does not exactly represent what takes place in the actual working of this apparatus, as part of this velocity is imparted to the condensing water in order to carry it into the boiler.

All useful work in an injector is done at the expense of a part of the external work done during evaporation; but as every particle of heat energy contained in the steam as well as all that part of the external work done during evaporation that is not theoretically required to pump the water into boiler (and consequently dissipates in friction thereby raising the feed temperature), returns to the boiler, there is every justification in saying that we have in the injector an apparatus which gives 100 per cent. efficiency. Notwithstanding this fact, the injector is not always the best means for supplying boilers with water. The selection of a suitable boiler feeder requires careful consideration in each particular case, and is governed by varying circumstances. Perhaps the best method of dealing with this question will be to establish the following distinct classes and deal with each of them independently:—

1. The water is taken from any convenient source and delivered to the boiler directly, no economisers or heaters of any description being employed.

2. A heater is used, and the temperature of the feed is thereby raised by means of the exhaust steam from engines; or, as an alternative, the exhaust steam is first purified and then mixed with the feed water directly.

3. Water from any convenient source other than the condenser discharge is passed through economisers.

4. An exhaust heater and economisers are used, the feed being pumped through both in series.

5. The engines are worked "condensing," and the condenser water, as well as all steam-trap discharges and other hot water available is collected in a hot well, and pumped through economisers into boilers.

6. The boilers are fed by means of an excentric pump on main engines directly, taking water at about 110 degrees Fahr. out of the condenser discharge well.

In cases Nos. 1 to 5, it has been assumed that an independent feed pump is used, worked by boiler steam, exhausting to the atmosphere in all cases excepting Nos. 2 and 4, in which the exhaust steam along with the exhaust from main engines, is supposed to pass through a heater or mix with the feed directly, as the case may be.

Case No. 1.—This instance is the most favourable for injectors, and their adoption is a distinct advantage. As already explained, there is no loss of energy in the working of an injector, whilst in the case of a pump a considerable amount of heat is wasted with the exhaust-steam. Moreover, the amount of steam must be sufficient to do the necessary useful work, besides overcoming the frictional resistances, and the heat generated by the dissipation of these is not capable of being re-utilised as with an injector.

The smaller a pump, the greater the proportion of loss of energy to useful work done. The relative efficiency compared with that of injectors further depends on the boiler pressure and the type of pump used.

The efficiency of a boiler feeding appliance may conveniently be expressed either as a part of the useful work done in the pump plus the energy generated in the boiler, or as a part of the useful work done in feeding same alone, the former method also being a direct method of ascertaining the saving of fuel that might be expected in the event of a change being made.

The energy put into the pump equals $\beta\ [JH+P\ (V-\rho)]$ foot lbs. per lb. of water delivered to the boiler, where β = weight of steam used per lb. of water, J = mechanical equivalent of heat (778), H = total heat per lb. of steam, P = pressure in lbs. per square foot, V = volume per lb. of steam and

ρ volume of one lb. of water = about 0·016 cubic feet. Again, the total energy generated in each lb. of water in pump and boiler equals $JH + PV$—pρ, where p = absolute pressure of water when entering pump; p and ρ, being comparatively small, effect the result of above two equations only so slightly that they may safely be neglected. We now can write :—

$$\text{Efficiency} = \frac{(1-\beta)\,(JH+PV)}{JH+PV} = \frac{1-\beta}{1}$$

This can be clearly seen by consideration ofthe following :—

$JH+PV$=total energy per lb. of water in boiler.

$\beta(JH+PV)$=energy used up in feeding 1 lb. of water to boilers.

$JH + PV - \beta\,(JH + PV) = (1 - \beta)\,(JH + PV)$ = Total energy minus energy used in feeding=energy available for useful work.

$$\text{Efficiency} = \frac{\text{Energy available for useful work}}{\text{Total energy generated,}}$$

therefore above equation.

From this it will be clearly seen that the efficiency is directly dependent on β, and this is regulated by the boiler pressure and type of pump employed.

However, the loss in the case of a pump is much more apparent if expressed in B. T. U. per lb. of water over and above the small losses that occur in the case of an injector through heat radiation, and the diagrams Figs. 2 and 3 therefore give these losses in this way. It will be noticed that one curve is also given in each diagram for a pump, actuated from the main engine directly. In the calculations this has been taken to be a single cylinder engine for the pressure of 60 lbs. per sq. in., and as a double expansion engine in the case of 140 lbs. per sq. in., the mechanical efficiency in both cases being assumed to vary from 84 to 70 per cent. according to the size of engine. The proportions which have been assumed for the "Duplex" pumps are given in diagram in Fig. 4, and those of the "Cameron," or flywheel type pump, in Fig. 5.

Case No. 2.—Where an exhaust heater is employed, the question as to whether a pump or injector is most suitable, depends on the amount of exhaust steam at disposal and the heating surface of the heater.

The usefulness of this auxiliary apparatus may be directly represented by the "amount of heat which it is capable of adding to the feed if same enters at a fixed temperature," say 60° Fahr. Injectors generally will deliver through heaters if required; but owing to the high temperature of the feed when entering the latter, it is questionable if any appreciable difference would occur in the final feed temperature.

Injectors may be said to be more efficient than pumps working in conjunction with exhaust heaters, if the energy wasted with the exhaust steam of pump exceeds the difference between the heat absorbed by feed during its passage through the heater in the case of pump and injector respectively.

If the average temperature of the steam in heater is assumed 200° Fahr., and the increase of temperature of the feed while passing through injector at a certain pressure is expressed by the empirical formula $t_2 - t_1 = 30 + 0{\cdot}5\,p$ (p being boiler pressure in lbs., per sq. in., by gauge) we may easily calculate that minimum temperature of feed from pump after having passed through heater, below which the application of the injector to take the place of the pump would prove advantageous. Fig. 6 represents these minimum temperatures for varying initial feed temperatures (which are assumed the same for both cases) and boiler pressures, in diagrammatic form. It is necessary to first ascertain the loss in pump by means of diagrams Figs. 2 and 3. The formula for the increase of temperature of the feed whilst passing through injector, gives results which agree very nearly with those obtained in actual practice, with injectors designed to deliver the feed at as low a temperature as possible.

If, on the other hand, all greasy matter is first extracted from the exhaust steam, and this is then mixed with the feed directly, a much greater proportion of its heat is put to a useful purpose, and the comparative efficiency now depends upon the amount by which the pump is capable of taking the feed hotter than the injector.

If the working conditions will not, in the case of an injector, permit the feed to be heated to a temperature nearly as high as the maximum at which the pump will deal with it satisfactorily, the application of the former would result in no economy; for the contrary to be the case, the feed temperature would not have to be lower by more than the difference that would occur if the exhaust steam from the pump was continually added to the feed water. Diagrams No. 2 and 3 will, if substituting degrees Fahr. for B.T.U., give the difference in temperature at 60 and 160 lbs. Boiler pressure, which if exceeded between the initial feed temperatures in the case of pump and injector respectively, will make the pump the more suitable apparatus of the two.

The possibilities of improvement, however, are not yet exhausted with the above. Where the feed is comparatively cold — say 60° to 80° Fahr. — the application of an exhaust injector is at all times a paying investment if the circumstances admit of this.

The exhaust steam injector may be regarded as a combined injector and feed water heater, and if of good design will raise the feed temperature by 80° to 100° Fahr., by means of exhaust steam alone. It is, however, important that an ample supply of fairly dry exhaust steam be at hand, and the pattern of injector selected be suitable for the pressure carried on boilers. Up to 60 or 70 lbs. steam pressure, injectors worked by exhaust steam alone are suitable, whilst above this and up to 110 or 120 lbs. pressure the compound pattern exhaust injector, in which a small auxiliary live steam jet is introduced to obtain the additional energy required, is usually adopted. For pressures higher than this it is usual to employ a special apparatus, consisting of an exhaust and a live steam injector coupled in series, the former feeding the latter and this the boiler. This type of injector can be made to suit almost any pressure.

The saving obtained by the use of exhaust injectors is rarely less that 4 per cent. or 5 per cent., and in some cases reaches as much as 12 per cent. and even 14 per cent.

Whenever the condensed exhaust steam is returned to boiler by means of an exhaust injector or otherwise, the utmost care is necessary that it is first freed from all greasy matter, as this, if allowed to pass into boiler, forms a thin coating on the plates, which owing to its non-conductivity results in serious overheating of the latter.

Case No. 3.—In the case of economisers being used great care is necessary in arriving at a decision as to whether a pump or injector is the most suitable appliance for feeding the boilers, as actual saving of fuel is not the only point to be considered. The economy of pumps as compared with injectors increases inversely as the mean temperature of the flue gases whilst passing through the economisers, and it decreases with the amount of heat added to the feed whilst passing through injector. It will generally be found that, if economisers do their duty properly, the pump is more economical than the injector; but the prolonged life of economisers when they receive hot water from an injector is usually worth the sacrifice of economy caused by the use of injector in such a case, as on the average it seldom amounts to more than 1 per cent. of the total fuel burnt.

It is also imperative that an injector should be carefully selected with regard to size so that it will permit of feeding constantly, as it is dangerous to allow the water in economisers to evaporate whilst they are standing idle. This fact makes an injector unsuitable where a great variation exists in the steam consumption, as the amount of feed can only be regulated down to a certain limit;

but this difficulty may often be overcome by the use of two injectors in place of one and by working either one or both of these as may be required. The widest range is obtained if the two injectors, instead of being of equal capacity as is usually the case, bear a ratio of about 2 to 1, as the amount of feed can then be reduced to less than one-third of the maximum which is sufficient in most cases.

Case No. 4.—The same remarks apply in this case as if exhaust heater was used alone (Case 2), and this in conjunction with the feed pump can with advantage be replaced by an exhaust injector where possible.

Case No. 5.—Where engines are worked condensing and the condenser water, along with all steam-trap discharges, is returned to boilers, injectors are often not applicable owing to the high initial feed temperature so obtained; but where circumstances do permit their use, a correct decision may be arrived at by careful consideration of the same points as in case 3.

Case No. 6.—Boilers which are fed through economisers with a direct acting excentric pump on main engines, are obviously supplied with water in a very economical manner, as the exhaust steam is condensed and thus nearly all its heat is returned. In such a case it is, however, essential to have a standby for feeding the boilers when the main engines are at a standstill, and it is customary to employ injectors for this purpose.

In conclusion, the writer would point out that the selection of a suitable boiler feeding appliance is also governed by numerous other circumstances. In a small place, for instance, where the duties of engineer are often entrusted to an inexperienced man with numerous callings to fill up his time, simplicity of the plant in every respect is a very desirable, if not essential, feature, and should be given preference to a slight saving of fuel. An injector of good design is, in such a case, admirably suited for its purpose. In small installations the economy that might under certain circumstances be derived from the use of a pump does not usually justify their additional first cost.

In modern locomotive practice injectors have become almost universal and many of the leading railway companies are now adopting the exhaust type of locomotive injector with the result of considerable saving of fuel in the end.

Injectors also have the advantage that they require much less attention than pumps in general, as the absence of moving parts does away with lubrication, adjustment and continued repairs. On the other hand they are not quite so well suitable where the feed water contains much hardness, as the formation of a scale on the interior of the cones soon results in the unsatisfactory working of the apparatus. Such scale can be removed by soaking the parts affected into a 10 to 1 solution of hydrochloric acid in water, the limey film being thereby softened when it can easily be removed. The formation of this scale does not take place to any appreciable extent whilst the apparatus is at work but rather immediately after it is stopped, as the thin film of water remaining on the cones is quickly evaporated by the heat radiation from steam pipe, thus adding a thin layer of lime every time when put out of action. It is therefore in such a case advisable to feed constantly so as to reduce the number of stoppages to a minimum.

It is impossible to lay down any general rules that are applicable in every instance; discretion and careful consideration are the only means for arriving at a correct decision as to whether a pump or injector is better suited for any particular case.

On Some Conditions Governing the Production of Iron and Steel Castings.

By PERCY LONGMUIR.

III.

EACH of the various stages followed in the production of a casting contributes it quota to the success or otherwise of the final product, and one stage cannot be specially watched to the exclusion of others. Taking the more general of these stages it will be found that the chief determining conditions are: —

1. Composition of the metal.
2. Initial casting temperature.
3. Preparation of the mould.
4. Method of melting, including in the case of white iron and steel oxidation and absorption of gases.
5. The presence of mechanically held foreign matter, sand, etc., and blowholes.
6. Shrinkage cracks and strains which may be due to—
   - (*a.*) Faulty feeding,
   - (*b.*) Faulty moulding, or, as is more usually the case,
   - (*c.*) Faulty design of pattern.
7. After-treatment in the case of white iron and steel.

The majority of castings are judged by one or a combination of the following factors—

A. General appearance and truth to pattern.

B. Ease of machining.

C. The mechanical properties of test-bars forming part of the casting.

D. Resistance offered to the percolation of water or steam under pressure.

Obviously a waster due to condition 3 is at once shown in the appearance of the casting either before it leaves the foundry or at any rate during its progress through the machine shops. Ease of machining in the case of grey-iron castings, and mechanical properties in the case of all castings, are a function of composition and structure. Therefore, in the case of failure to meet factor B or C chemical analysis and microscopical examination will generally reveal the cause. Oxidation and absorption of gases are determined by the method of melting and the composition, features which chiefly affect white iron or steel. The remedy in both cases is found in thorough dead melting in conjunction with the presence of a deoxidising element in the finished casting. Thus with white iron for malleable cast the silicon should be run as high as is permissible with the thickness of the casting. With steel, manganese should be present in the *casting** in decisive quantity, and an addition of 0·08 per cent. aluminium made to the ladle or crucible before casting. Unfortunately, reliable data as to the influence of oxides on steel is missing, a remark also applicable to the presence of gases. However, careful melting and the presence in the final product of either silicon or manganese is a reliable safeguard.

The appearance of the skin of a blowhole gives a clue to its cause; if an oxidation tint is shown then the cause is trapped air or mould gases. In the absence of such a tint the blowhole represents a cavity formed by the liberation of gas from the steel at or near the solidification point. In the former case the method of pouring or the condition of the mould is at fault; in the latter

* A considerable loss of manganese occurs on melting which according to the conditions of melting will vary from 30 to 50 per cent.

the composition of the steel, or its condition at the moment of casting.

Shrinkage or contraction faults may be due to the casting "pulling" against a hard mould, or to unsuitable feeding. Opinion differs as to the form of suitable feeding, but whatever the form it should be such that the shrinkage of the liquid metal is met entirely by the reservoirs serving as "feeding heads." Contraction from solidification downwards must be given free play, a necessity which, if the casting is likely to "pull," involves releasing that portion of the mould likely to bind it. Naturally, contraction of this type will mean more or less warping to overcome which the pattern should previously be set out of truth to the extent of the warp. Familiar examples of such "setting" are found in grey-iron castings such as lathe beds, etc., in steel castings, such as propeller blades and the like. In discussing grey-iron castings, reference was made to varying the rate of cooling in different parts of one casting; such methods are, when necessary, applicable to castings of any metal. Intricate steel or white iron castings are often saved from contraction strains by stripping at the moment of solidification, releasing cores, etc., and placing the red-hot casting in an annealing oven in order to obtain uniformly slow cooling.

Having reviewed some of the more salient governing conditions, it is proposed to conclude these notes by reference to one source of failure. As already noted, a failure due to faulty moulding is self-evident, similarly if the test-bars fail to reach the desired standard, chemical analysis will show whether the composition is at fault, and in the case of malleable cast-iron or steel microscopical examination will show whether the annealing conditions are at fault. When the cause of failure is shown then the remedy is naturally suggested. It is only just to state that the majority of wasters can be traced to a definite cause in one or other of the conditions already outlined. But occasionally a casting will, from no apparent cause, hopelessly fail to meet a specification. The casting may be perfect externally, of absolutely correct chemical composition, and so far as known, of right treatment, yet it may be, if of cast iron, that the transverse results are a few hundredweight short, or if of steel, that the elongations and bending angles are too low. Similar features in the case of steam metal alloys have been dealt with by the writer in earlier issues of this Review, and it will be remembered that the mechanical and water-resisting properties of these alloys were markedly affected by the casting temperature, *i.e.*, condition 2 of the table heading this article.

It needs no saying that in modern iron or steel foundry practice the governing conditions indicated can be and are, by the exercise of suitable care, readily controlled. The greatest variable in a well organised foundry operated under efficient chemical supervision is found in this factor of casting temperature, and to it the majority of mysterious failures are attributable. A casting poured with dull metal and therefore containing "cold shuts" rounded corners and so forth obviously shows the influence of too low a casting temperature, but within the range of perfect fluidity much temperature variation is possible, which, whilst it does not affect external appearances, certainly does

Analysis.						Casting Temperature °C.	Max. Stress. Tons per sq in.
Combined Carbon.	Graphite.	Silicon.	Manganese.	Sulphur.	Phosphorus.		
0·52	3·40	1·78	0·28	0·04	0·27	1400 1350 1245	9·7 14·1 10·6

affect the inherent properties of the metal. Many experiments have been conducted on various types of grey cast iron, and in no case has this influence failed to show in the properties of the castings. For instance, a series of transverse test bars poured at short intervals from a five-ton ladle yielded various results, the highest being 35 cwts. and the lowest 23 cwts. on a section of 2 in. by 1 in., the bars being placed on knife edge supports 3 ft. apart. The table on the preceding page gives results* obtained from a high quality grey iron which are even more instructive.

These results represent castings poured from one and the same crucible within a few minutes of each other. Chemically, the three bars are identical, mechanically they are as shown. Many experiments on different irons have yielded similar variations, and it has been proved that, as with steam metals, the porosity varies with the tensile results, so in the case of cast iron and "high" or "low" temperatures yield castings which sweat under water test.

In trying to eliminate these variations in grey iron due to varying casting temperature, only negative results have been obtained. No matter how the properties are improved by the treatment given, the original variations are always present. This is possibly of greater moment in the case of malleable cast iron and steel, which depend for their success largely on the treatment given. As an example, a typical white iron is given below and the results obtained from it, in the condition of cast, annealed and heat treated.

The analysis of the white iron "as cast" was as follows:—

Combined carbon.	Graphite.	Silicon.	Manganese.	Sulphur.	Phosphorus.
3·40	none	0·39	0·05	0·02	0·02

The improvement in properties due to treatment will be noted, nevertheless the treated castings have not reached one level. Thus in spite of the chemical changes induced by annealing in ore and the complete structural rearrangement, the influence of casting temperature still holds good. That a revolutionary treatment such as is involved in drastic ore annealing, does not remove the original variations is of high practical moment. It will also be noted that the castings treated by the "short anneal" also maintain a relative distance apart in properties.

Casting Temperature °C.	Condition.			
	As Cast.	Annealed in ore.		Heated to above 1000 °, and slowly cooled.
	Max. Stress. Tons per sq. in.	Max Stress. Tons per sq. in.	Elongation per cent. on 2 in.	Max. Stress. Tons per sq. in.
1320	10·7	20·6	1·0	18·6
1230	15·9	29·2	3·5	24·0
1120	12·1	26·5	2·0	21·6

Whilst in the case of steam metal alloys and cast iron, comparatively wide ranges of casting temperature are offered, this range is with steel necessarily restricted, owing to the higher melting points involved. Thus, in the crucible process it is well within the range of possibility to cast hard tool steel at too high a temperature†, but under ordinary conditions, mild steel by the same process can hardly be over-heated. Fairly similar conditions hold good in the case of open hearth steel, for the milder the steel, the less the danger of obtaining too high casting temperatures. The surface-blown Bessemer converter

* These and the following results are extracted from the Author's paper "On the Influence of Varying Casting Temperature," *Journal of the Iron and Steel Institute*, No. 1, 1904.

† Such an ingot would be termed scalded.

gives, of the three methods, the widest range of casting temperature.

If in the case of mild steels the probability of exceeding the fair casting heat is remote, it would appear that casting temperature as a governing condition is of comparatively little moment. For example, the following tensile tests do not differentiate between the properties of two sets of castings poured from one crucible at two distinct temperatures.

speaking of differences in casting temperature, such differences apply to the range of *perfect* fluidity from the fair casting heat downwards, the range terminating once the metal becomes "stiff" and likely to result in "cold shut" castings.

A harder type of crucible steel is shown in the table at bottom, representing results obtained from three steels of practically similar composition cast at three distinct temperatures:—

Analysis.					Casting Temperature °C.	Condition.					
						As Cast.			Annealed.		
Carbon.	Silicon.	Manganese.	Sulphur.	Phosph.		Max. Stress Tons sq. in.	Elong. per cent. on 2 in.	Reduction of area per cent.	Max. Stress Tons.	Elong. per cent.	Reduction of area.
0·29	0·14	0·92	0·06	0·02	1611	30·9	7·5	13·1	29·1	19·5	18·4
					1560	30·1	7·0	12·1	28·4	18·5	18·4

In the cast condition, bending angles of the two steels were identical. After annealing, the first steel bent through an angle of 180 deg., and in so doing developed no apparent flaw. The second one annealed simultaneously with the first, and under precisely similar conditions *fractured* on reaching an angle of 105 deg. This difference in behaviour to bending stresses forms the only one noted in the properties of the two steels. Tests on similar low carbon crucible steels, where the fair casting heat can hardly be exceeded show that differences in casting temperature do not result in any marked difference in properties as shown by the tensile test. When

Here the influence of varying temperature is shown on both tensile and bending tests, but it is worthy of note that the "fair" heat has not been exceeded. The survival of this influence noted in the case of white iron is also manifested in these results from a medium carbon steel.

Generally speaking open hearth steels follow the same order as crucible steels, in that the higher the content of carbon the greater the chances of variation in casting temperature. Evidently, then, low carbon steels are—if judged by tensile tests alone—not likely to be seriously influenced by the comparatively limited temperature variation

Analysis.					Casting Temperature.	Cast.				Annealed.			
Carbon.	Silicon.	Manganese.	Sulphur	Phosph.		Max. Stress Tons.	Elong. per cent. on 2 in.	Reduction of area.	Bending angle °.	Max Stress. Tons.	Elong. per cent. on 2 in.	Reduction of area	Bending angle °.
0·47	0.22	1·04	0·05	0·016	1500 °C	38·6	4·3	6·0	30	37·1	13·0	15·2	80
0·50	0·20	0·96	0·05	0·017	1481 °C	36·4	3·0	5·4	23	36·4	7·5	9·2	60
0·47	0·20	1·00	0·05	0·016	1431 °C	31·0	2·5	3·8	10	22·5	3·0	8·1	35

Analysis.					Casting. Temperature.	Max. Stress. Tons per sq. in.	Elongation per cent. on 2 in.	Reduction of area per cent.
Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.				
0·29	0·07	0·16	0·07	0·06	"High"	24·2	9·5	18·0
					"Fair"	27·2	24·0	32·3
					"Medium"	27·0	12·5	17·5
					"Low"	25·5	8·0	12·0

within the range of fluidity. However, if this range can be widened by obtaining higher initial temperatures, then the influence of varying casting temperature is decisively shown on the tensile properties of resulting castings. The perfect fluidity of low carbon steel from a surface-blown converter is familiar, a fluidity which necessarily involves high initial temperatures. In order to investigate the wider range of fluidity so obtainable, Messrs. D. Rennie & Co., of Glasgow, conducted for the writer a number of experiments, employing a two-ton Robert converter for the purpose. All conditions other than casting temperature were identical, the analyses of the cold castings agreed exactly, and annealing conditions were perfectly comparative for each series of castings. Thus the appended steels represent four sets of mild castings poured from *one* ladle within a few minutes of each other. The castings were annealed together under precisely similar conditions.

The fact that castings poured within a few minutes of each other and from the *same* ladle yield elongations rising from 9½ per cent. to 24 per cent., and falling again to 8 per cent., is of some moment to steel founders working to a specification. As a further example the appended results are worthy of note.

Analysis.					Casting. Temperature.	Max. Stress. Tons per sq. in.	Elongation per cent. on 2 in.	Reduction of area per cent.
Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus				
0·28	0·15	0·29	0·06	0·05	"High"	30·9	15·5	16·4
					"Fair"	28·0	33·5	45·6
					"Medium"	30·3	27·5	39·2

Here again the values are obtained from annealed castings.

In this and the foregoing example, it will be noted that maximum stress is not appreciably affected, but the elongations speak for themselves. As an example of higher carbon steel by the same process, the appended are given.

These results are from annealed castings, and the influence of temperature is again shown on the elongations, the

Analysis.					Casting. Temperature.	Max. Stress. Tons per sq. in.	Elongation per cent. on 2 in.	Reduction of area per cent.
Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.				
0·51	0·11	0·42	0·06	0·05	Fair heat to low heat, cast from same ladle at short intervals.	34·5	22·5	27·3
						36·7	20·6	16·7
						36·2	6·5	8·4

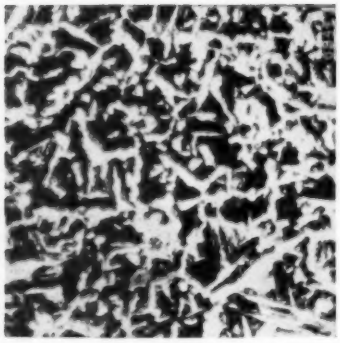

FIG. 20.—ELONGATION PER CENT. 6·5.

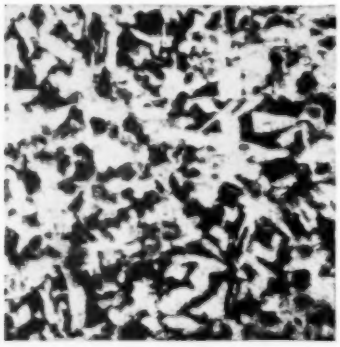

FIG. 19.—ELONGATION PER CENT. 20·0.

MAGNIFIED 58 DIAMETERS.

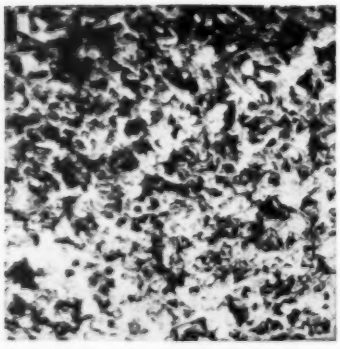

FIG. 18.—ELONGATION PER CENT. 22·5.

first one representing for cast steel of 0·51 per cent. carbon an exceedingly high value. The structures of these three steels are reproduced in Figs. 18, 19, and 20. Generally speaking, the influence of varying casting temperature on the structure of steel may be summarised as follows: "Fair" casting heats favour a less distinct type of structure than either "high" or "low" heats. The latter are always characterised by a distinct type of crystallisation, showing sharp junctions between the ferrite and the pearlite, features which recall the "loose," "interlocked," and distinct structures of steam metal alloys.* Thus the interwoven type of structure in Fig. 18 gradually gives place with a falling casting temperature to the exceedingly sharp structure of Fig. 20. Irrespective of mechanical properties, the survival of this distinct structure through a prolonged annealing is of much significance, showing that, as with white cast iron so with steel, initial defects are not removed by heat treatment. Three castings from the same ladle, simultaneously annealed over a period of three days (72 hours), are not brought to one level as regards tensile properties, nor are their structures equalised by equal treatment. Steel castings possessing such a structure as Fig. 20, characterised by the sharp demarcation of pearlite and ferrite, inevitably leak or sweat under hydraulic test. Evidently these sharp boundaries offer routes of penetration, a feature doubtless aided by the slight expansion due to internal pressure when under test. Probably a better illustration of this feature is found with practically pure iron. An iron of the following analysis,

Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.	Aluminium.
0·08	0·04	0·06	0·03	0·01	0·04

was melted and castings obtained from it representing two distinct temperatures, viz., 1653° C. and 1613° C., the former corresponding to the "fair" heat. The resultant structures are reproduced in Figs. 21 and 22. The

* *Feilden's Magazine*, November and December, 1903.

two photographs are perfectly typical, and it will be noted that the crystal junctions of Fig. 22 are far more distinct than those of Fig. 21. This feature is common to all pure metals, and with them low casting temperatures always yield comparatively wide crystal junctions, even in some cases developing apparent interspaces between two adjacent crystals. The behaviour of such a type of loose crystallisation under water pressure can be readily imagined.

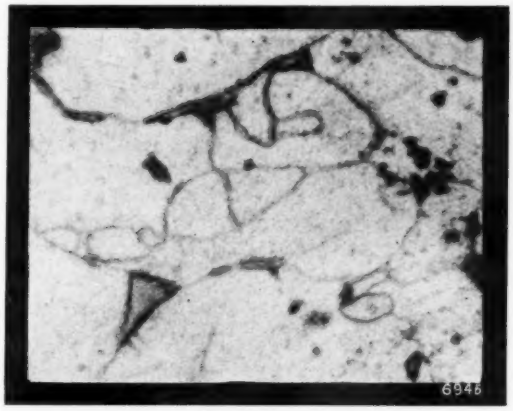

FIG. 21.—NEARLY PURE IRON AS CAST. CASTING TEMPERATURE, 1653° C.

Excluding mild crucible steels which cannot be overheated, it is evident from the tests given that the properties of steel castings are influenced by varying casting temperature in a similar manner to those of general alloys.* This influence holds good with all types of cast iron and survives a treatment involving decomposition of one of the constituents and a complete structural rearrangement. The practical importance of this governing condition justifies the somewhat lengthy treatment given to it, however, as it influences the whole range of foundry metallurgy and too much attention cannot be given to it. By far the greater number of mysterious failures on test may be traced to this one cause, and whilst the difficulties of overcoming it are great they are nevertheless not insurmountable. For instance one steel foundry with which the writer is familiar is regularly producing castings showing elongations of from 30 to 35 per cent. on 2 inches, whilst bending bars bend parallel without fracture. The determining conditions conducive to such regularity have been indicated, the greatest variable, that of casting temperature, can be and is controlled by carefully noting the appearance of the molten metal. The "fair heat" of any metal or alloy necessarily varies with the contour and weight of the casting, thus by associating a certain appearance of the molten metal with a given type of casting and *its resultant properties*, invaluable data as to the influence of varying casting temperature is obtained. The knowledge is necessarily intuitive, but it is a

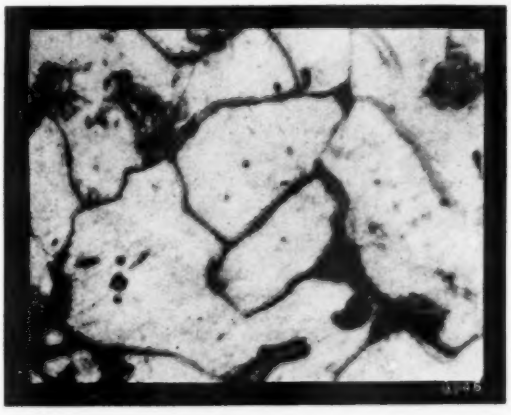

FIG 22.—NEARLY PURE IRON AS CAST. CASTING TEMPERATURE, 161° C. (MAGNIFIED 360 DIAMETERS.)

* *Feilden's Magazine*, November and December, 1903.

comparatively reliable guide and its exercise will lead to very regular results.

Brittle Steels.

In the example quoted of a mild crucible steel it will be remembered that tensile results were not influenced by differences in casting temperature. Structurally these two steels showed the usual difference, viz., the sharper division between pearlite and ferrite in the low temperature casting. The only visible effect of this difference in structure being that under bending test the "sharp" one fractured at an angle of 105 degrees, whilst the interwoven structure bent parallel without flaw. At the first glance brittleness appears out of place in an article dealing with castings, for the greater number of failures due to this cause are found in forged products. However, a second glance will show that forged products represent castings (ingots) hammered or rolled at a red heat into industrial form. It has already been shown that with castings one type of defect initially present survives mere heat treatment, whether of long or short duration. Naturally the question arises as to whether this defect survives a combination of work and heat treatment such as is found in the act of forging.

However, in the first place it may be well to recall a few characteristics of the type of brittleness to which so much attention is now being given. That a mild steel which under tension yields a good elongation and strips of which may, in the cold, be doubled and squeezed together without flaw, should be brittle is apparently a contradiction. Yet many of these so called mysterious fractures occur in steel of excellent mechanical properties as judged by tension and bending tests. Further chemical analysis often proves the steel to be of good quality and microscopical examination does not always reveal the cause of sudden failure. In short these failures are found in steel which in the course of manufacture has been under careful supervision and inspection and which has successfully met stringent specifications. The latter are obviously framed to exclude material unsuitable for the purpose intended and are presumably based on known data.

Turning back to the first page of this article, the seven determining conditions there outlined for sand castings are equally applicable to steel cast in a metallic mould. Let it also be added that in the larger number of cases a defect in the ingot persistently survives, but that it is usually detected by the rigid system of inspection followed. Evidently, then, mysterious failures are not due to ordinary causes, and are beyond the experience on which usual specifications are based.

The fact that ordinary tests do not select dangerous material gives a reason for the wide efforts in progress towards one which will decisively answer the question, "Is the steel safe?" Of these tests, those introduced by Professor Arnold, Mr. E. G. Izod, and Messrs. Seaton & Jude have been indicated in other issues of this REVIEW. The alternating stress test of Professor Arnold admirably answers the question of safety, and at once selects a dangerously brittle steel. The alternating stress results subsequently given were obtained from this machine.

Reverting to the influence of casting temperature on mild crucible steel the following results show that the effect, if any, is not shown in tension tests.

This table embraces two steels of nearly uniform composition in three conditions, viz., cast, annealed, and forged, each condition including two distinct casting temperatures. The difference in properties between the forged and cast condition is well shown, but the difference in casting temperature does not influence any one of the three conditions. It will, however, be noted that 98A in the bending test fractures on reaching an angle of 160 degrees. It may be well to add that the conditions, apart from casting temperature, are perfectly comparative. 97A and 98A were annealed together, whilst 99 and 100 were forged

Analysis.						Casting Temperature °C.	Condition.	Max. Srress Tons sq. in.	Elong. per cent. on 2 in.	Reduction of area.	Bending angle °.
No.	Carbon	Silicon.	Manganese.	Sulphur	Phosph.						
97	0·36	0·22	0·89	0·02	0·02	1550 to 1600	cast	35·8	12·5	12·5	75 broken.
98	,,	,,	,,	,,	,,	1470 to 1500	cast	34·2	11·5	17·4	80 ,,
97A	,,	,,	,,	,,	,,		cast annealed	27·0	17·5	17·4	180 unbroken.
98A	,,	,,	,,	,,	,,		cast annealed	28·2	18·5	18·0	160 broken.
99	0·37	0·18	0·87	0·03	0·02	1550 to 1600	forged	40·9	27·5	54·0	180 unbroken.
100	,,	,,	,,	,,	,,	1470 to 1500	forged	40·1	28·0	50·0	180 ,,

under exactly similar conditions. The following table gives the alternating stress results:—

270 Reversals per minute, $\frac{9}{16}$ in. stroke, test piece $\frac{3}{8}$ in. by $\frac{3}{8}$ in.

No.	Reversals to complete fracture.
97	68
98	48
97 A	122
98 A	62
99	546
100	172

In these results the influence of the low casting temperature is well shown; thus steel 98, even after annealing, only just approaches the value obtained from 97 in the *cast* condition. The forged results are worthy of very careful consideration, especially the comparatively low resistance of No. 100 to alternating stress. At the risk of repetition, it may be well to state again that each of the foregoing conditions were, as judged by tension tests, practically equal in value. In this fact, the significance of the results are to be found, for if with mild steel—not overheated, but cast at too low a temperature—the usually accepted tests do not select brittleness, there is considerable risk of a dangerous steel going into service. It is not intended to advance faulty casting temperatures as the source of all mysterious fractures; as a matter of fact, the data yet available is insufficient in character to warrant any sweeping conclusions with reference to forged steels. With cast metals this influence is paramount, and the results given, showing its survival through various forms of heat treatment, emphasise its importance in everyday foundry work. The fact that brittleness under alternating stress induced by a low casting temperature is not removed by forging, opens out a new field of inquiry into investigations of fractures in mild steel of otherwise high ductility. Herein lies one source of disease worthy of careful and detailed study.

Postscript.—Since completing the foregoing, the writer's attention has been called to an article by Dr. Wedding on "Defects in Ingot Iron Castings," which is noted in the metallurgical section of last month's issue. With mild steel Dr. Wedding emphasises the importance of varying casting temperature on the formation of blowholes and shrinkage cavities. Such defects are of considerable moment; they are, however, entirely secondary to the influence of casting temperature on the mechanical properties. With average castings, blowholes and shrinkage cavities are detected on machining; further, their occurrence due to the source indicated is extremely erratic, whilst the influence of casting temperature on mechanical properties is constant. The whole of the tests given in the present article were obtained from metal perfectly free from blowholes, shrinkage cavities, or shrinkage strains. From any given metal or alloy melted and cast under careful supervision, perfectly sound castings may be obtained within the range

of fluidity. Externally these castings will show no difference other than that the higher the temperature the greater the adherence of sand and the rougher the surface. On machining the castings the appearance will be identical, but on testing either by tension, torsion, transverse, bending or alternation the properties of the *sound* castings will vary with the initial casting temperature.

Compounds of Carbon and Silicon with Metals.

By heating together finely-divided iron and lamp-black in the electric furnace, carbon-iron alloys containing up to 4·96 per cent. of carbon have been prepared by Hempel. With cobalt, products containing up to 8·45 per cent., and with nickel up to 6·25 per cent., of carbon were obtained. In the case of iron and cobalt, the greater part of the carbon in the cooled product is chemically combined; but in the case of nickel, nearly the whole of the carbon in the final product is present as graphite:—

Platinum can take up 1·2 per cent. of carbon, whereby it becomes brittle.				
Copper can take up to 0·03 per cent. of carbon.				
Silver	,,	0·04	,,	,,
Gold	,,	0·31	,,	,,
Manganese	,,	0·47	,,	,,
Chromium	,,	2·23	,,	,,
Tungsten	,,	3·3	,,	,,

By fusing a mixture of the reduced metal with powdered silicon crystallised from zinc, silicon cobalt alloys containing up to 19·3 per cent. of silicon were obtained, the products being extremely hard and brittle. The corresponding nickel alloys contained up to 19·95 per cent. of silicon. With mixtures of silicon and carbon, together with cobalt and nickel respectively, amounts of silicon less than 1·4 per cent. have little influence on the quantity of carbon taken up; but if the silicon be present in excess, the amount of carbon taken up is less, the greater the quantity of silicon in the final product. Commercial zinc is stated to be quite free from carbon. For the determination of the carbon in metals, the author, says *Engineering*, recommends Weyl's method of dissolving the metal by the aid of the electric current. A piece of glass tubing is made, with one end in the form of a flat plate having a hole in the middle. The material is placed on this plate and the tube is immersed in dilute hydrochloric acid (HCl), so that about one-third of the material is covered. The current flows through a platinum wire in contact with the material being examined. The undissolved carbon is determined by combustion with chromic acid by Ullgren's method. In the case of metals, such as platinum, the author finds that the metal is quickly dissolved by approximately the theoretical amount of *aqua regia*, if the mixture of metal and acid be heated to 130° C. in a sealed tube. The undissolved carbon may then be determined by combustion, and any carbon dioxide formed determined gasometrically.

The New Dock and Transit Sheds at the Manchester Docks.

By H. L. HUNTER.

OWING to the progressive increase of traffic on the Manchester Ship Canal, extension of the dock system has been for some years past an urgent necessity. In the year 1900 the directors of the canal decided upon the construction of two new docks together with warehouses, railways, and roads. They were fortunate in finding a most suitable site for the proposed works in a plot of land covering an area of about 150 acres, the greater part of which was formerly occupied by the Manchester racecourse. Of this area 21½ acres will be devoted to the new docks, and the remaining 128½ acres to quays, warehouses, railways and roads.

Fig. 1 is a block plan showing the position of the new docks, which are designated No. 9 and No. 10 respectively. The first of these is now completed and will be opened for traffic during next month. Work will be commenced upon the second at the earliest possible moment.

The water area of the No. 9 dock is 15½ acres, the length along the centre line being 2,700 ft. and the width 250 ft. The depth of water will be 28 ft., corresponding with that of the Ship Canal. As may be seen by reference to the plan, the longitudinal axis of the dock lies almost due east and west. The western end is left open, giving access to and from the canal, and the eastern end is closed by a concrete wall. On the northern and southern sides the walls consist of two series of concrete piers and arches. The arches are open in front, and the space beneath them is partly filled by pitched slopes supported at the back by concrete walls between the piers.

It should here be explained that the old Salford quay formerly extended across the entrance to the new dock. The face of this quay consists of a solid concrete wall nearly 10 ft. thick, and was of great assistance to the contractors during the work of excavation, because it acted as a very efficient dam for holding up the water of the Ship Canal.

Excavation of the basin was commenced in the autumn of 1902, and occupied a period of about two years, the total quantity of material removed being nearly 900,000 cubic yards.

The contractors' plant used for the purposes of excavation included :—Four Dunbar-Rushton steam navvies with buckets each holding 15 cubic ft., 12 locomotives, 300 tipping and other waggons, and 12 steam cranes. Eight pumps of various types and capacities were provided for dealing with any water that might be encountered, but, as it turned out, very little water entered the cuttings, even at the lowest level. Hence only one pump was fixed, and this was never used to more than one-sixth of its full capacity, and then only for a few minutes at a time. In addition to the plant mentioned, the contractors laid down about 15 miles of railway track, 4 miles of this being in the workings of the new basin.

The chief points of interest connected with the construction of the dock centre in the north and south walls and quays, of which Fig. 2 is a typical cross section. The end or east wall was put in solid to form a boundary wall of the foundation for a future grain elevator.

The piers on the north side, 113 in number, are spaced 25 ft. apart centre

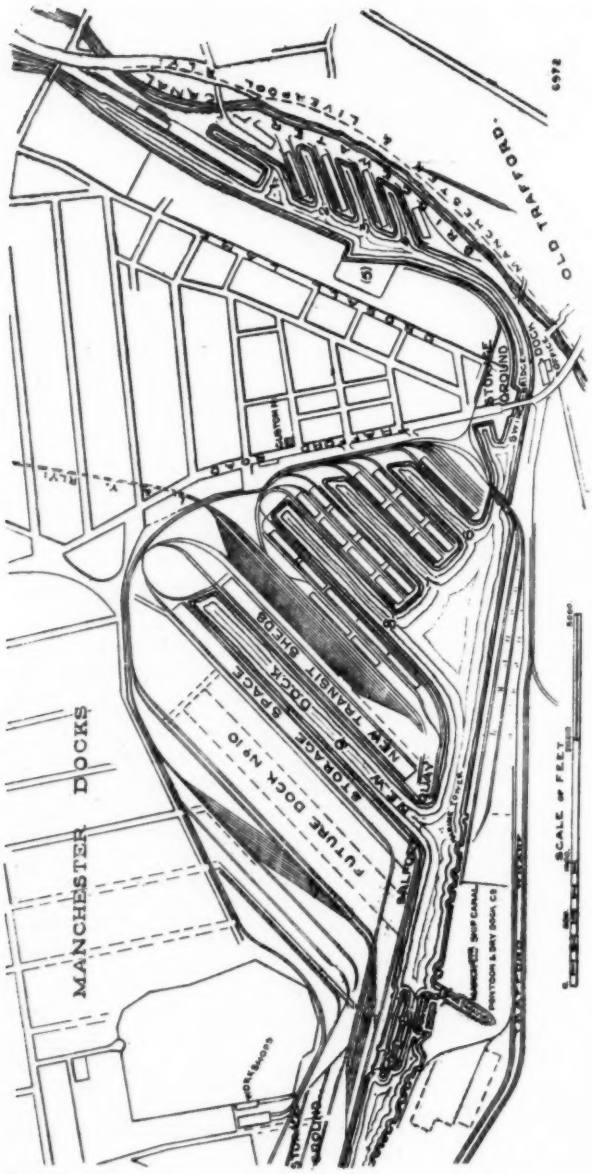

FIG. 1.—PLAN OF MANCHESTER DOCKS.

to centre. The foundations were formed by excavating trenches 10 ft. wide by 20 ft. long, to a depth of 3 ft. 6 in. below the level of the dock bottom, but in some cases it was necessary to take the trenches 5 ft. or 6 ft. deeper, in order to reach the soft sandstone substratum. Blocks of stone were used as "plums" in the bottom of each trench to economise the concrete which was deposited between and over them, and brought up to the level of the dock bottom. Above the footings so formed, an 18-in. course of concrete was laid 8 ft. wide by 20 ft. long, and upon this the pier was built 6 ft. wide to the length of 20 ft. and the height of 18 ft. 5 in. to the springing of the arches (see Fig. 3).

The foundations and piers were extended backwards for a further length of 16 ft. 8 in., making the total length measured from the face equal to 36 ft. 8 in., the foundations of the hinder portion of the piers being stepped upwards to a height of 5 ft., thus making a total height of foundation and pier in this part only

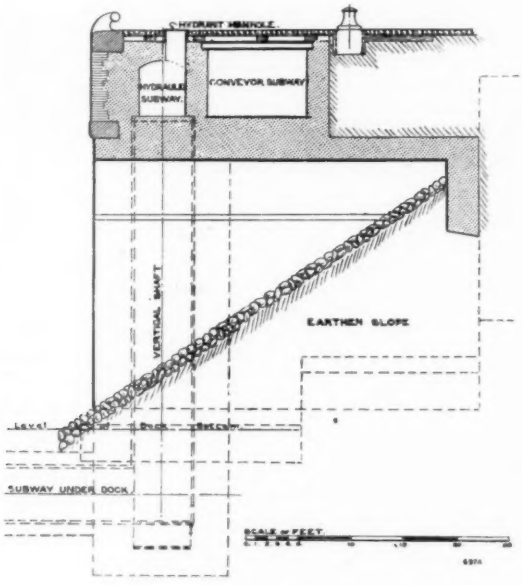

FIG. 2.—CROSS SECTION OF DOCK WALL.

18 ft. 5 in., while the total height of the front portion is 23 ft. 5 in. The top of each pier is shaped to form suitable skewbacks for the arches on either side.

The spaces between the back ends of the piers are filled by concrete curtain walls 3 ft. thick by 8 ft. 9 in. high, these walls being for the purpose of tying the piers together, and of acting as abutments for the slopes beneath the arches.

The arches have a clear span of 19 ft. each, a thickness at the springings of 7 ft. and at the crown of 2 ft., the intrados being of segmental form with a radius of 13 ft., and a rise above the springing line of 5 ft. The arches extend back from the face of the dock to the concrete walls connecting the piers, a distance of 33 ft. 8 in.

The space beneath each arch is partly filled by a slope consisting of rammed earth with a fall of 1 in $1\frac{1}{2}$ from the concrete wall down to the bottom of the dock, these slopes being faced with limestone pitching 15 in. thick.

All the piers were built up in courses about 3 ft. thick, between shutters shored up by strong timber framework. Each layer of concrete was allowed to set for about three days before the forms were raised for the deposition of the next course. The arches were moulded on timber centring supported by the framework used for shoring up the shutters for the piers. Four centring ribs were employed for each arch, being covered with lagging formed of planks, nailed in position and the joints between them being filled with clay. The concrete was deposited upon the centring, well tamped, and allowed to set for three weeks before the centring was lowered.

Great care was taken not to damage the timbering, and for this reason six sets of moulds and centring ribs were found sufficient for the execution of all the concrete work in the dock walls.

In the southern wall of the dock the construction is very similar to that described above, but, owing to the fact that the length is considerably less than that of the northern wall, only

ninety-nine piers were required—serving for the construction of ninety-eight arches and slopes.

It should be explained, however, that, in order to provide foundations for the long range of transit sheds on the south side of the dock, ninety-three of the piers were extended back for a distance of 112 ft. 4 in., making the total length of these piers 149 ft.

These extended piers were built with foundations in three steps, one of 5 ft., as in the case of the piers on the north side of the dock, and two others of 8 ft. 6 in. and 5 ft. respectively. The hindermost portion of the pier, 112 ft. 4 in. long, 6 ft. wide, and 16 ft. deep, is finished at a height of 6 ft. above the level of the crowns of the arches facing the dock.

A fender course is formed immediately above the arch crowns, this course being formed of limestone in blocks 18 in. deep by 30 in. wide and of varying length.

Above the fender course, the face of the dock wall is built in blue brick with a backing of red brick, both laid in 2 : 1 Portland cement mortar. This facing wall is 14½ in. thick, backed by 40 in. of concrete, and above it is a granite coping.

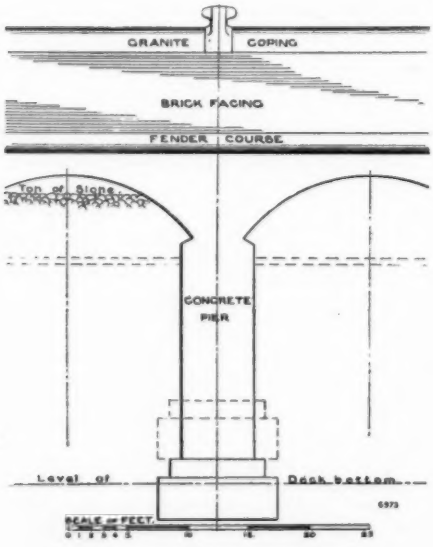

FIG. 3.—PART ELEVATION OF DOCK WALL.

The inner face of the concrete backing forms one side of a tunnel extending beneath the quays on the northern, eastern and southern sides of the dock, intended for the reception of hydraulic and ordinary water mains and electric cables. For the sake of distinction this tunnel is hereafter termed "hydraulic subway." It measures 4 ft. 6 in. wide by 5 ft. 6 in. high, and, as shown in Fig. 2, has an arched roof in which are formed the various manholes and hydrant, fuse, and switch boxes.

Parallel with the hydraulic subway is another tunnel running along the southern side of the dock, the two subways being separated by a concrete wall 2 ft. thick. A similar tunnel runs parallel with the hydraulic subway on the northern side, but only extends from the eastern end to a point halfway along the dock. The latter subways provide accommodation for two electrically-driven belt conveyors for the purpose of transporting grain from vessels lying alongside the quay into an elevator with a capacity of 40,000 tons to be built at the eastern end of the dock.

Each conveyor subway measures 9 ft. 9 in. wide by 6 ft. 6 in. high. The side walls are of concrete 2 ft. thick and the roof is built of 8-in. rolled steel joists, spaced 30 in. apart, with intervening panels of concrete 8 in. thick reinforced by a network of corrugated wire mesh embedded at a distance of about 1 in. from the lower surface.

The conveyors are driven by electric motors installed in chambers situated at intervals of 150 yards along each subway. These motor chambers are 31 ft. long by 5 ft. wide, being separated from the subway by a 9-in. brick wall in which is a cast-iron door. The motor shafts extend through the brick wall into the subway, running in pedestals fixed in wall boxes. Let into the concrete at convenient distances apart are grain chutes of cast-iron, through which grain will fall down to the belts after it

has been raised from the holds of vessels alongside the quays.

The outside surface of the roofs and sides of the hydraulic and conveyor subways were thickly coated with tar, over which strips of felt were laid, and then two other coats of tar.

Ample provision has been made for the removal of surface water outside the subways by gulleys and pipes discharging into the main drains.

The subway floors have a slight slope longitudinally, so as to carry off any possible leakage down to surface drains, laid across the subway at suitable distance and covered by gratings. These drains also discharge into the main drainage system.

Above the roofs of the subways sand and cinders were deposited to form a bed for the sleepers of the railway lines running along the quays. The rails having been fixed in position on longitudinal sleepers, a roadway paved with setts was constructed for the whole width of each quay, level with the coping of the dock walls.

This coping is formed of granite blocks 2 ft. thick, in which bollards are fixed at intervals of every 60 ft., these being anchored by long bolts extending vertically and horizontally into the concrete.

Granite stairways are built in the brickwork and granite coping in convenient positions, these stairways extending downwards to the water level of the dock.

Beneath the level of the dock bottom and at the distance of 300 ft. from the western end is a cast-iron subway crossing the dock and connecting the northern and southern ends of the hydraulic subway, communication being given at each side of the dock by a vertical shaft.

Each of these shafts, 40 ft. deep, is lined with cast-iron segments bolted together to form a ring 6 in. in diameter. The shaft is divided into three sections by iron gratings and ladders which extend from grating to grating.

The subway, 5 ft. in diameter and of the sectional form shown in Fig. 4, is lined with cast-iron rings 4 ft. 6 in. long, made up of nine segments, the tube

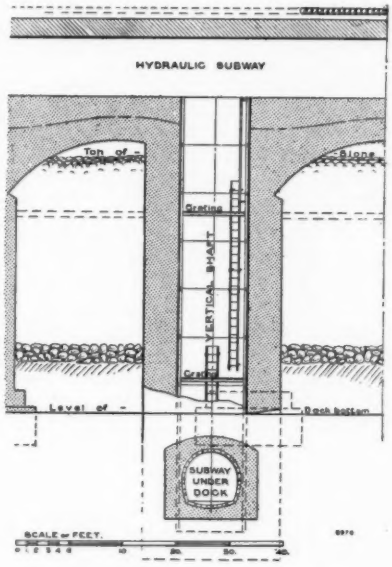

FIG. 4.—PART LONGITUDINAL SECTION OF DOCK WALL.

being supported by a foundation of concrete encased in the same material to the thickness of 15 in. Above the concrete is about 2 ft. of filling forming part of the dock bottom.

Inside the subway a level floor is formed by a bed of concrete with a maximum thickness of 6 in.

The walls of the new dock have been built up to and connected with the old Salford quay, and within the last few weeks that portion of the old quay, which had been of great assistance by effectively sealing the entrance to the dock, has been removed, partly by blasting with ammonite to a depth of 5 ft. or 6 ft. below water level, and partly by means of a new mechanical rock breaker, of the type now being used in the rock section of the canal in connection with the work of deepening the waterway by 2 ft. Recesses were left in the walls at the points of junction between the old and new work, and when the jagged edges left by blasting had been dressed by divers, these

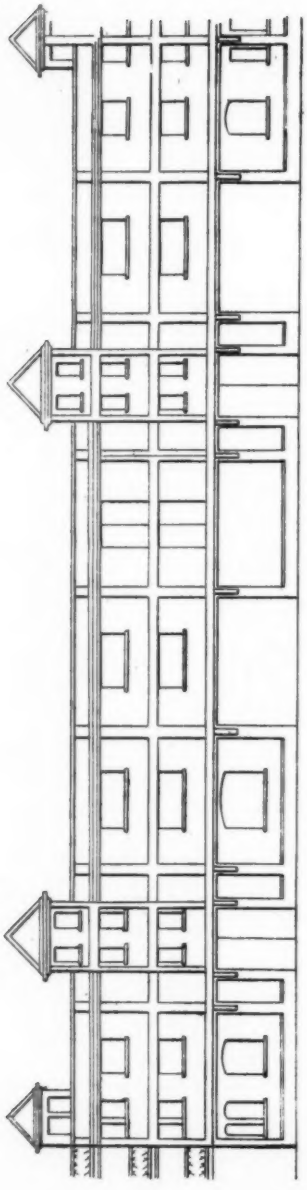

FIG. 5.—HALF ELEVATION OF SHED: SOUTH FACADE.

recesses were fitted with heavy timber frames and bullnoses as a protection at the corners for the hulls of incoming and outgoing vessels.

All the concrete used in the new dock was mixed in the proportions of 1 part Portland cement, 2 parts sharp sand, and 6 parts washed gravel or broken stone. The total quantity of concrete used in the construction of the dock and the foundations for the new elevator amounted to 110,000 cubic yards, involving the consumption of 17,000 tons of Portland cement, of which about 8,000 tons were supplied by Messrs. Martin Earle & Co., of Rochester.

In the construction of the facing walls, fender course, and copings of the dock, the approximate quantities of material used were 1,600 cubic yards of blue brick, 3,000 cubic yards of red brick, and 60,000 cubic feet of granite coping and fender course. About 100,000 cubic yards of limestone pitching were required for the slopes beneath the arches and 60,000 cubic yards of setts for paving the roadways along the quays.

The works were designed by and are being executed under the superintendence of Mr. W. H. Hunter, chief engineer to the Manchester Ship Canal, Mr. George Williams, son of Sir E. Leader Williams, being the resident engineer, and Messrs. Lovatt & Co., of Wolverhampton, the contractors. The total cost of the new dock and auxiliary works will probably exceed £230,000, without taking into account the cost of land or of the new transit sheds.

The gigantic range of buildings technically described as transit sheds, extend for a distance of about 2,250 ft. along the southern quay of the new dock. They are built entirely of ferro-concrete, a material which is particularly suitable for structures of this character.

This portion of the works included the construction of five transit sheds, one in the centre having a length of 450 ft., while each of the other four measures 425 ft. long. All the sheds have the uniform width of 110 ft., and a height of 45 ft. from ground level to the top of the flat roof. Each shed includes three

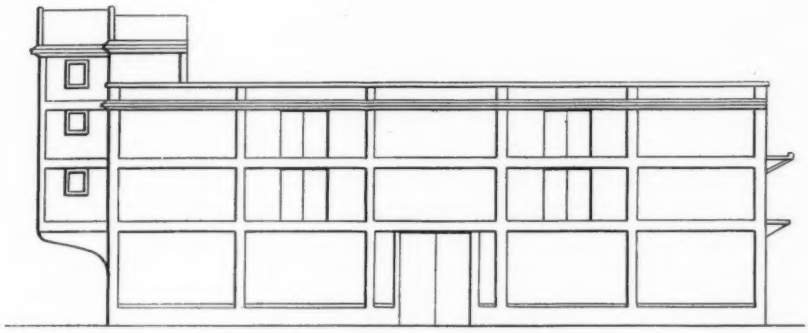

FIG. 6.—END ELEVATION OF SHED.

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floors, and the whole series is connected by gangways at the levels of the first floor, the second floor, and the roof.

Taking the roof into account, the total floor area of the sheds amounts to nearly 1,000,000 sq. ft., or about 23 acres. Although very large, this area is by no means excessive, as past experience at the Manchester docks indicates the desirability of apportioning some 45,000 sq. ft. of shed room for every 100 ft. run of quay accommodation.

Ample facilities are provided for dealing with merchandise passing through the sheds. The whole front of the sheds facing the dock can be thrown open for the reception of goods, which will be carried directly into the ground floor either on railway wagons or lorries, and raised by means of numerous electric cranes and hoists to the first and second floors and the roof, whence they will be transhipped by electric quay cranes, of which there will be an abundant supply. In unloading a vessel the reverse process will take place. To facilitate the landing of goods, a permanent platform projecting about 3 ft. 6 in. has been built at the level of the first floor, and hinged loading platforms are provided in a continuous row at the level of the second floor.

At the back of each shed there are five teagles, or hoisting towers, which commence at the level of the first floor and extend above the roof so that goods can be lifted from the ground to the top of the building, or transferred from one floor to another.

Between these towers the first floor of the building is extended so as to form a verandah or balcony 12 ft. wide, serving to shelter vehicles from the weather, and in each shed three openings or hatchways are formed in this verandah for use as additional loading stations. Opposite these hatchways doors are provided on each floor, and above them are catheads for raising and lowering goods.

Fig. 5 is a half elevation of one 425 ft. shed, and shows three of the hoisting towers at the back. The other turrets indicated in this drawing are structures on the flat roof, which form the upper portion of staircases inside the building. Fig. 6 is an end elevation typical of all the sheds.

Foundations for all the sheds are provided by the horizontal extensions of the ninety-three piers mentioned in connection with the construction of the dock walls.

All these piers are tied together by concrete arches, which were built in a very economical manner by cutting out the earth to the required curve, and then by filling in concrete between shutters. The surface of the earth, having been carefully smoothed, formed the bottom of the mould. This mode of procedure avoided the necessity for

the expense of deep excavations, the erection and removal of arch centrings and re-filling the spaces excavated.

As previously stated, the piers are spaced 25 ft. apart, centre to centre, and upon each of them brick footings are built 22 ft. apart, centre to centre, the dimensions of the footings being 6 ft. by 7 ft. 9 in. by 4 ft. high.

In each of the 425-ft. sheds there are eighty-five of these footings, and ninety-five in the 450-ft. shed.

Cast-iron baseplates, 4 ft. in diameter, are fixed upon the brick piers, these baseplates affording a bearing for the vertical reinforcement of the ferro-concrete columns, which transmit the weight of the entire structure to the foundations. Thus the sheds and dock wall are tied together into one huge monolithic mass, capable of withstanding the most powerful disturbances.

The columns are spaced 25 ft. apart longitudinally and 22 ft. apart transversely, the outer rows forming part of the walls. Between the columns the wall thickness is only 4 in., this being amply sufficient, as the weight of all the walls, floors and roofs is taken by the main girders and finally by the main columns.

Each shed is divided into two parts by the construction of a ferro-concrete partition wall, all openings in which are closed by two fireproof doors, one on each side. Although the whole of the construction is absolutely fireproof, it is quite possible that fire might break out in some of the goods stored, and these partition walls are intended for the purpose of enabling the staff to deal more efficiently with any outbreak.

The main columns are 20 in. square by 16 ft. 3 in. high on the ground floor, 14 in. square by 10 ft. 6 in. high on the first floor, and 12 in. by 10 in. by 10 ft. 6 in. high on the second floor.

The net heights of the three stories of the building are:—Ground floor 14 ft. 3 in., first floor 8 ft. 4 in., second floor 8 ft. 7 in.

On the ground floor each column contains ten steel bars of vertical reinforcement, connected laterally by ties spaced about 6 in. apart, measured vertically.

Before the building of the columns was commenced, a semi-hemispherical cast-iron shield, with an opening in the top, was fixed over the cast-iron base of the column, The reinforcement was then erected and temporarily fixed in position, together with four angle bars to protect the corners of the concrete from accidental injury. These bars were held in position by strips of steel riveted to them at intervals of a few inches apart, the free ends of the strips being turned inwards and attached to the main reinforcement.

The column mould was then erected and properly stayed, one side of the mould being left open to give access for deposition of the concrete layer by layer. The same procedure was adopted for all the columns in each building from the base up to the level of the first floor, so that the concreting could be done simultaneously, or as nearly so as possible, on all the columns.

Concrete was filled into the moulds in layers 6 in. thick, this work being done with a trowel, and on the completion of each layer a piece of board 6 in. wide was nailed across the open side of the column mould until the mould was completely filled and boarded up.

All the concrete used in this way was mixed rather wet, so that it might the better be able to penetrate between the various members of the reinforcement, and to fill all voids inside the moulds.

Near the top of each column the mould was extended on either side so as to form two brackets for the purpose of giving additional support to the main beams of the building.

The number and area of the steel bars constituting the column reinforcement was varied in accordance with the loads to be carried, and as a matter of fact there are no less than ten different types of column design on the ground floor alone, although the general system of construction was that described above.

As soon as the columns had been carried to the level of the first floor, timber moulds were built up for the formation of the main beams, secondary

beams, and floor slab. The main beams measure 12 in. wide by 18 in. deep, the secondary beams are $\frac{1}{5}$ in. wide by $\frac{2}{1\frac{1}{4}}$ in. deep, and the floor slab is 5 in. thick.

After they had been erected and stayed, the moulds and centring for the floor slab were thoroughly washed down and treated with limewash. Then about 1" in. of concrete was deposited along the bottom of the beam moulds, and into this layer, **U**-shaped stirrups of steel hooping were inserted in sets of three, each set at intervals of 6 in. apart. In these stirrups were laid three straight bars of steel which were covered with concrete. After them came three more bars, bent up towards each end. These in turn were covered with concrete, and three straight bars were laid near the top of the mould, which was next filled up with concrete. The formation of the beam was completed by the insertion of more **U**-shaped stirrups in an inverted position, these stirrups being forced into the concrete before it had commenced to set.

A very similar process was followed in the moulding of the secondary beams, the only difference being that the dimensions were smaller and fewer bars and stirrups were required as reinforcement. The mode of setting the two lower sets of bars, whose function is to take up all tensile stresses in the beams, constitutes the chief peculiarity of the Hennebique system, the middle bars, sometimes termed "rising bars," being supposed to be particularly useful in sustaining the bending moments due to the loads on the beams. Another peculiarity is that M. Hennebique does not rely upon adherence between concrete and metal to form the bond between these materials. Hence the extremities of the tension bars are fish-tailed to form a species of "lewis" in the concrete, and the stirrups are curved over at the ends.

When the concrete of the main and secondary beams had been allowed to harden for four days, the floor slab was moulded by depositing successive layers of concrete alternately with rows of steel rods, the rows being laid first in one direction and then in another, so as to form a rectangular network separated by layers of concrete about 1 in. thick.

On completion of the first floor, timber moulds were erected for the next section of the columns, and when these were finished the moulds were fitted up for the beams and slab of the second floor, the method of construction adopted for this, and for the flat roof, being exactly the same as that already described.

The ferro-concrete walls were built by filling the spaces between the main columns with a network of steel rods, and depositing concrete around them between timber shuttering. The flat roof was finished by the erection of ferro-concrete parapets along the side and back walls, the front of the roof being protected by a parapet of cast iron anchored down into the concrete of the walls.

That part of each hoisting tower which projects above the roof level was continued back for about 10 ft. to afford housing for the electrically-driven hoist. The other roof structures are the turrets covering the staircases, to which reference has been made previously. At either end of each shed, in the corner nearest the dock, a large block of concrete was built up to serve as a foundation for the electric crane, which is installed on the roof at each of these points.

All hooks and other fastenings for doors, loading platforms, hoists, and other structural and mechanical details, were embedded in the concrete during the process of moulding with the object of avoiding the necessity for cutting away and making good at a later period.

The columns on the ground floor were calculated for a normal load of 340 tons each, those of the first story for a load of 226 tons, and those of the second story for a load of 113 tons. All the floors and flat roofs were calculated for a normal load of 3·4 cwt. per square foot.

It is satisfactory to note that the official tests conducted upon the columns and floors have demonstrated the fact that the strength and rigidity of the

construction is considerably in excess of the standard demanded by the specification, a result which may be attributed to the incorporation of far more steel in the shape of reinforcement than is customary in French practice. Engineers on the Continent generally adopt proportions that would not be accepted in this country, although they may appear to be justified on theoretical grounds. Still, the teaching of practical experience is that the strains actually experienced may be greater than those taken as the basis of calculation, and if the bond between the concrete and the steel should be impaired in consequence of long-continued vibration, the resistance of the construction as a whole must clearly be reduced to no inconsiderable extent. For these reasons, engineers will do well to insist upon an ample margin of safety when designing buildings and other structures of reinforced concrete. So far as concerns the buildings described in the present article, there is sufficient reason for the belief that the essential conditions of strength, stiffness, and stability are adequately assured.

In their construction some 75,000 cubic yards of concrete were employed, including 12,000 tons of Portland cement, and nearly 6,000 tons of steel for the purpose of reinforcement, the total cost of the buildings and equipment being over £220,000.

The general design of the sheds was prepared by Mr. W. H. Hunter, chief engineer to the Manchester Ship Canal, and the details of the ferro-concrete construction by Mr. L. G. Mouchel, M. Soc. C.E. (France), who is the agent in Great Britain for the Hennebique patents. The contractors were Messrs. Lovatt and Brueder, of Wolverhampton, who have executed the works in a most efficient and satisfactory manner.

Testing and specifying Portland Cements with Reference to Standard Specification.

By J. KERR ROBERTSON, A.M.Inst.C.E.

HAVING regard to the erratic individualism that has characterised so many specifications and has led to so much unnecessary multiplication of types, to indite a formal argument in favour of standardization would be to insult the intelligence of the readers of this paper. The agitation which commenced during the last decade of the nineteenth century amongst many engineers and manufacturers for the standardization of many articles which find general use in all works of construction, and upon the quality and reliability of which are based the calculations of the designer, fortunately led to the formation of a committee with which was entrusted—in joint interests of buyer and seller — the preparation of the standards of manufacture and dimensions of such articles.

This Engineering Standards Committee, formed in 1901, was supported by the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, the Institution of Electrical Engineers, representatives of Government departments and manufacturers, and has after much deliberation issued standard specifications for rails, steel beams, tees, angles, Portland cement, tramway rails, electric traction equipment, etc., and already there are signs that traffic in these articles will follow the channels so carefully prepared for it.

What effect this standardization will have on the future development of the manufactures so treated is difficult to foretell, but past history clearly shows that the competition of commerce to meet and anticipate the always increasing demands of engineers' and architects' specifications was responsible for the high standard and wide variety in the manufacture of the articles now docketed and specified for production and use.

The gradual development and steady improvement in the quality and reliability of manufactured constructive materials during the past eighty years is aptly illustrated by the history of Portland cement, and, as showing the obstacle to this progress any standard specification would have been, a brief sketch of the history and our present knowledge of this material must bear witness.

The introduction of Portland cement as an important material of construction is comparatively recent, dating from 1830.

Portland cement consists of a mixture of clay and chalk in certain proportions, depending on the carbonate of lime in the chalk and the silica and alumina in the clay, the proportion of the latter being 20 per cent. of the mixture when it contains not more than 15 per cent. of iron in the form of oxides.

The analysis of the materials as generally employed in the manufacture of Portland cement in England are :—

Clay.		Chalk.	
Silica	68·45	Lime	56·0
Alumina ...	11·64	Carbonic acid	44·0
Carbonate of lime ...	0·75		
Oxides of iron	14·80		
Soda of alkalies	4·00		

The chief object to which attention is first directed in the process of manufacture is to obtain an intimate combination of the materials. This is accomplished by the agency of water and mechanical contrivances, and upon the satisfactory manipulation of the mixture at this stage depends much of the quality of the finished product.

The water is then drained off and the mixture is put in kilns where it is decarbonized and becomes "clinker." The clinker is then passed through the grinding mills, and becomes the cement with which everybody is familiar.

Such, then, is an outline of the manufacture of Portland cement, but the success of the process depends on the care and intelligence of the manufacturer, as the whole of the cementitious quality of the product lies in the manipulation of the selected components.

In order to gauge the quality and strength of cement engineers apply the following tests:—

1. Analysis of chemical composition.
2. Degree of fineness of grinding.
3. Weight.
4. Tensile strength.
5. Rate of setting.
6. Soundness.

Chemical Composition.—A good sound Portland cement on analysis should show the following chemical composition:—

Lime	60
Silica	23
Alumina	7
Oxide of iron	4
Sulphuric acid	0·5
Alkalies	0·5
Magnesia	1·5
Moisture	3·5

In any chemical analysis of a sound cement lime should not exceed 61·5 per cent., magnesia 1·25 per cent., sulphuric acid in the form of sulphites and sulphates equivalent to 1·25 per cent., not less than 23 per cent. of silica, and 12 per cent. of alumina and oxide of iron, and ·75 per cent. of moisture.

The presence of a high percentage of lime in cement is indicated by a high tensile strength and subsequent fissuring of the concrete. An excess of clay in the original admixture is indicated by a high percentage of alumina, and tends to make a quick-setting cement. The defect can be overcome by aeration, a "cooling" resulting in the partial hydration of the lime, or by the addition of gypsum, which is allowed by some authorities in small quantities.

Fineness.—One of the most marked differences in Portland cement as used now and fifty years ago is the fineness to which the clinker is reduced in the mills. Even so lately as 1870 the fineness of cement was regulated by passing through sieves with meshes ranging from 1,600 to 3,000 per sq. in., while now the sieves specified range from 5,776 to 32,400 meshes per sq. in.

Finely-ground clinker produces a quick-setting water-tight cement, and as the particles hydrate simultaneously no fissures or lines of weakness are produced in the mass, as so often occurs where unevenly ground cements are employed.

Weight.—It was early recognised that heavy and hard clinker produced the best cements. And in order to ensure a heavy clinker being finely ground, engineers specify the weight of the cement, as the light clinkers easily produce a very finely ground cement. The earlier cements were specified to weigh from 112 to 120 lbs. per bushel, but owing to the fineness of modern cements the weight of a bushel has been reduced to from 100 to 110 lbs.

This test is hardly a true criterion of quality, as cements lose weight with age, and it may be held generally that a very finely ground cement showing a comparatively great weight contains an excess of lime.

Strength. — All the improvements which have been introduced in the process of manufacture have been directed to obtain an increase in the strength of cement.

In works where cement is being employed in large quantities it is usual to test samples taken from each delivery, its use being prohibited until such tests have been made and the cement approved by the engineer. The test of tensile

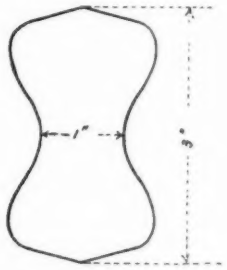


FIG. 1.

strength is therefore of the greatest importance.

To obtain reliable strength tests briquettes are made 1 in. deep of the form shown in Fig. 1, having a sectional area of 1 sq. in. at the plane of fracture. Much care is required in the preparation of these briquettes, as upon their soundness depends the reliability of the test.

As cement may set any time between ten minutes and five hours after mixing it is important that the quantities made up should not unnecessarily protract the operation, and for this reason it is usual not to mix more of the test material than is sufficient to make up two of the above briquettes.

There are two methods of testing the strength of cements; either the cement can be tested pure, or as a test of its cementitious power with a mixture of standard sand. In the former the cement is not tested as a cement but as an artificial stone, and when tested in this manner experience has shown that a coarse ground cement will give higher results than a fine ground cement, while when mixed with standard sand and tested as a cement higher values of strength are obtained from the finer cements.

In any series of tests, a uniformity of result indicates a sound cement; great variations being objectionable.

In 1858 it was considered that a thoroughly sound Portland cement had been produced if a tensile strength of 177 lbs. per sq. in. was obtained after seven days. Little consideration was then given of the percentage of increase of strength during induration. The general conclusion as indicated by early specifications would appear to be that without weight a cement of great strength could not be obtained.

The specification of the Standards Committee relating to cement requires, that the test briquette shall withstand on an average not less than 400 lbs. per sq. in. after seven days and 500 lbs. per sq. in after twenty-eight days. The percentage of increase from seven to twenty-eight days being not less than 25 per cent. when seven days test falls between 400 and 450 lbs. per sq. in.; 20 per cent. when seven days test falls between 450 and 500 lbs. per sq. in.; 15 per cent. when seven days test falls between 500 and 550 lbs. per sq. in.; 10 per cent. when seven days test falls between 550 lbs. and upwards.

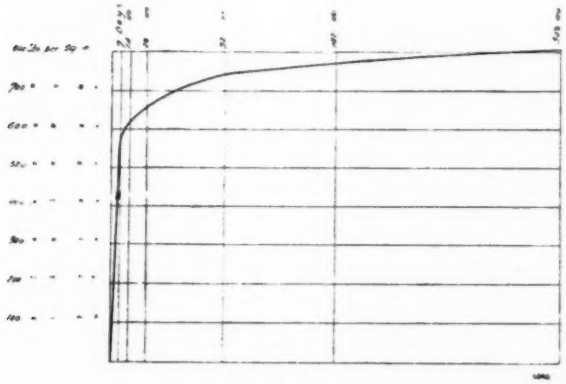


FIG. 2.

In the construction of works where cement is used in considerable quantities, and on the soundness of which depends the strength of the structure, numerous briquettes are usually made and tested systematically for tensile strength.

Fig. 2 shows, diagrammatically, the results of

such tests carried on throughout twelve months.

The cement shows a high tensile strength, pointing to an excess of lime, and increasing 14·3 per cent. in strength from seven to twenty-eight days.

In another series of six tests the result of a seven days test showed an average strength of 486·7 lbs. per sq. in., the greatest range of ultimate strength being 10·6 per cent., while the fourteen days test for the same cement gave an average on six briquettes of 556·2 lbs. per sq. in. with a range of strength of 15 per cent. while the twenty-seven days test gave an average of 659·4 lbs. per sq. in., with a range of ultimate strength of 5·4 per cent.

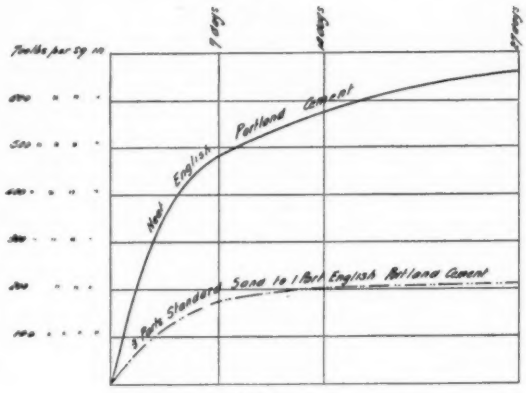


FIG 3.

The resistance curve of these tests is shown in Fig. 3, also the strength of the same cement tested as a mortar consisting of one part of cement to three parts of standard sand.

In the preparation of the test briquettes care should be observed to ensure the whole operation of mixing and filling the moulds being confined to ten minutes. In order to accomplish this the mixing of material and filling of two moulds will be found sufficient for one operation.

The reliability and value of mortar tests rests exclusively on the sand used, and the sand which has commonly been adopted as a standard, consists of silica sand which will pass through a 400-mesh sieve and be retained by a 900-mesh sieve.

To make up two standard test briquettes of three parts sand to one part cement, $7\frac{1}{2}$ ozs. of standard sand and $2\frac{1}{2}$ ozs. of cement will be found sufficient and will give a result slightly in favour of the cement, as against measuring in bulk, the specific gravity of cement being less than that of sand. After the sand and cement have been thoroughly mixed together dry, $6\frac{1}{2}$ to $7\frac{1}{2}$ drams of water should be added, according to the climatic conditions obtaining at the time. After thoroughly mixing again the mixture should be placed in the moulds in

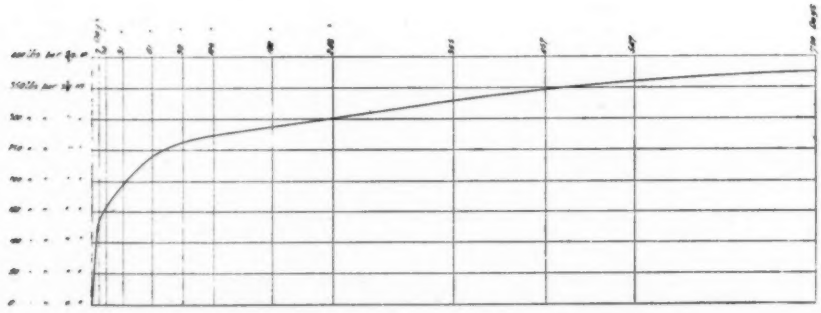


FIG. 4.

three or four layers and carefully and uniformly rammed with wooden rammer and hammer. The briquettes should then be left undisturbed for twenty-four hours, after which they should be placed in water, the greatest care being observed not to subject them to any shock until required for testing.

The results of a series of tests extending over a period two years, on mortar consisting of three parts standard sand and one part English Portland cement, made as explained above, are shown in Fig. 4, the percentage increase of strength from seven to thirty-one days being 46, from thirty-one days to six months 49 per cent., from six to twelve months 15 per cent., and from one year to two years 13 per cent.

The miscellaneous uses to which Portland cement is applicable requires that its properties should be capable of modification to comply with a variety of conditions, without destroying its fundamental and valuable characteristics. As the factor upon which the soundness of many engineering works—in which cement is largely used—depends is the rate of setting of the cement, it is imperative that cements should be obtainable with a wide range of time of setting.

The Engineering Standards Committee have adopted a classification of cements, relative to their time of setting, of three distinct gradations, designated as "quick," "medium," and "slow." "Quick" embraces all cements which set in not less than ten minutes nor more than thirty minutes; "Medium" cements set in not less than thirty minutes nor more than two hours; "Slow" cement shall not set in less than two hours nor more than five hours.

The rate of setting is tested by the gradual application to the surface of a pat of cement of an apparatus consisting of a rod weighted by the fixture thereon, of a sphere of brass and terminated by a "needle" $\frac{1}{16}$ in. square, the whole weighing $2\frac{1}{2}$ lbs. The cement is considered set when the needle fails to make an impression on the surface of the cement pat.

Soundness.—A cement is considered sound, if, after it has set and remained for a certain period under conditions similar to its permanent situation, it exhibits no indication of expanding, warping, cracking or blowing.

Cements are tested for soundness by preparing, on glass plates, small pats of cement or mortar about $3\frac{1}{2}$ in. in diameter, $\frac{1}{8}$ in. thick and as thin as possible at the edges. Twenty-four hours after preparation the pats should be placed in water (sea water for marine works), and after remaining immersed for twenty-seven days should show none of the above signs of unsoundness.

When the Le Chatelier test is applied to ascertain the soundness of cements the apparatus should not indicate a greater expansion after twenty-four hours' aeration than twelve millimetres, or six millimetres after seven days' aeration.

Thus there has been developed in specifying and testing Portland cements a certain procedure which at once indicates the points of weakness in manufacture and the lines along which future improvements will probably proceed, and it is impossible that any cause which will retard this progress, which is but an aggregation of individual enterprise, can be accepted by those who appreciate what still remains to be done towards realising an ideal cement.

It was for this reason that fears were entertained in some quarters that a standard specification would tend to produce an unquestioning level of intelligent specification which would become general; but the Standard Specification is so drawn up that, while it leaves the van open to advance, it methodically consolidates our present knowledge and requirements, and if all cement is in future manufactured to comply with this specification the Engineering Standards Committee have accomplished a great service of wide importance.

THE MONTH.

NOTWITHSTANDING the excellent records presented by the low-level electric railways of London, it would be unwise to disregard the lessons to be learned from two accidents which have taken place within the last few weeks on the New York Rapid Transit Subway. The first of these mishaps was a collision, in which a timber-built car was completely crushed between two steel cars in the same train, the latter vehicles being practically uninjured. The second accident, although unimportant in itself, serves to demonstrate how easily a train may be set on fire by short circuiting if one of the cars should be derailed. In this case, five cars with copper-sheathed timber bodies were completely destroyed, while two steel cars in the same train were not perceptibly damaged. The third rail is a very obvious source of danger in certain contingencies, and, in the interests of the travelling public, ought to be superseded by a safer method of conduction. As for the cars, it is clear that steel bodies ought to be insisted upon, being immeasurably safer than timber bodies against damage by collision and by fire.

Numerous formulæ have been published by British, American and Continental engineers for determining the proportions of concrete-steel beams. Some of these rules involve the use of the calculus, most of them are complicated, and all give results that differ to an appreciable degree. The confusion thus confronting the designer clearly tends to discourage the employment of the new material by engineers. With the object of simplifying the process of calculation, several empirical formulæ have been introduced, but these are not so serviceable as could be desired, because they merely assist the user to determine the value of the moment of resistance for a beam of assumed proportions. This is reversing the order of things which prevails in daily practice, where the object is to find the proportions of a beam from other essential factors. On another page we publish a series of simple rules which ought to be generally appreciated, for by their aid the required areas of concrete and steel reinforcement can be determined for any rectangular beam, if the load and span are known and if the length of the arm of the internal forces be settled to suit the convenience of the designer.

In a recent communication to the Engineers' Club of Philadelphia, Mr. Joseph T. Richards, chief engineer of maintenance of way to the Pennsylvania Railroad, discusses the design and operation of a modern freight yard, and gives as an example the plan of a yard designed by him for the Washington Southern Railway. The function of this yard is to pass through cars *en route* within the least possible time, the processes to be gone through being the change of engines, the classification of trucks, and the making up of fresh trains. The yard illustrated and described in this paper seems to be of most suitable design for the requirements of long trunk lines, and the author states that the time required to pass a train of eighty wagons through the yard, from the arrival to the departure tracks, should not exceed from two to three hours. This plan will be found of interest by many of our readers, and we may particularly direct attention to the arrangements for the inspection, cleaning, coaling and watering of locomotives in the most expeditious manner.

Some practical tests by Professor Carpenter at Cornell University are valuable as throwing light upon the effects obtainable by a new method of treating leather belts so as to fit them for transmitting a maximum amount of power with a minimum of initial tension. For the purpose of the tests two 4-in. single belts were used, one treated by the process, and the other in the condition supplied by the maker. The trials were conducted with initial tension varying from 82·5 lb. down to 5 lb. per

belt. In the former case the output per inch of width was 10 h.-p. for the untreated belt and 12·66 h.-p. for the treated belt, and in the latter the output was 0 for the untreated belt and 13·4 h.-p. for the treated belt. Taking next the initial tension of 30 lb. as fairly representative of that obtaining in practice, we find that the outputs per inch of width were 6·2 h.-p. and 9·2 h.-p. respectively for the two belts. Hence it becomes evident that a treated belt run quite slack is capable of transmitting more than double the power transmitted by an ordinary belt tightly laced up. So far as we are aware, the method of treatment forming the subject of the investigation by Professor Carpenter has not yet been adopted in this country, but the important results here stated show that it promises very considerable savings to all users of belt-driven machinery.

Since the application of an induction coil in the circuit, obviating the tendency of the mercury vapour lamp to go out at frequent periods, the only objection to this means of illumination is its peculiar colour. Still, the fact is that the light possesses all the elements that make it desirable for those who desire to see, rather than to be seen. It lacks the red rays which are more tiring and harmful to the eye than any other, and is well adapted for manufactories, drawing offices, photographic studios, and commercial offices. A typical installation in New York serves to suggest the usefulness of the mercury apparatus in electricity stations. The example to which we refer is in the accumulator hall of the New York Transportation Company. This room, measuring 302 ft. long by 42 ft. wide by 20 ft. high, was formerly illuminated by fourteen five-ampere arc lamps, but the lighting was inadequate, and the fumes from the storage cells interfered so considerably with the operation of the lamps that it became necessary to remove the mechanism from the hood of the lamps and to fix it under separate covers. Subsequently, ten mercury vapour lamps were substituted, with the results that all trouble was eliminated, and the consumption of current was reduced to one-half the amount previously required.

According to tests made in Paris with gasolene, kerosene, and 90 per cent. alcohol, it appears that the power output of the last-mentioned was nearly 20 per cent. greater than that of gasolene, while kerosene showed an advantage of about 12·5 per cent. The actual economy of power production naturally depends upon the cost of the fuel, but in view of the proposals made to remove the restrictions hitherto preventing the manufacture and application of alcohol for power purposes, it is probable that this form of fuel will come into very general use, especially for motor cars. In that event, the country will benefit by the extension of a British industry, and the public using the highways will not suffer as at present from the malodorous fumes left by every passing motor vehicle.

Notwithstanding the satisfactory appearance of the accounts published relative to the electric tramway undertakings in a few cities and large towns, it may be doubted whether the results are really so advantageous to the ratepayers as might be inferred from casual inspection of the balance sheets. So far as concerns the majority of municipal tramways it is evident, in spite of the most favourable treatment accorded by the authorities who prepare the accounts, that no profits are being made in aid of the rates. Even the avowed advocates of municipal trading are beginning to recognise the fact that tramway enterprise is of too speculative a character to be undertaken by public authorities. The development of motor traffic has brought the public face to face with the probability that the tramway system may be superseded, in progress of time, by services of well-appointed vehicles each carrying its own source of motive power, and capable of running on any streets and roads without the necessity of costly tracks. Should this probability

become a realised fact, the vast sums sunk in permanent way construction will be irretrievably lost, and easy-going ratepayers will find out too late that the heavy burdens they have allowed to be hung round their necks in the hope of future benefit have been borne in vain. Money already squandered cannot be recalled, but there is yet time to veto further reckless expenditure in the direction to which we refer.

Second only in importance to the completion of the irrigation system in Egypt proper, and the inauguration of similar works in the Soudan, is the necessity for improving and extending the Egyptian State railways. As the result of their studies, the Commission appointed to inquire into the administration of the railway system have come to the unanimous conclusion that the existing scheme of organisation is entirely unsatisfactory, and that the supreme control ought to be vested in an official with powers akin to those of a general manager in this country and responsible to a State Council, representing a board of directors. Traffic management is found to be inadequate owing to the lack of superior officers and an excess of the subordinate staff. Signalling arrangements are unsatisfactory, and the immediate provision of new passenger coaches and goods wagons is considered to be essential. These recommendations will meet with general approval, and so also will the suggestion that the gap existing between Assuan and Wady Halfa should be bridged without delay. By linking up the Egyptian and Soudanese lines a through connection will be established from Alexandria to Khartoum, which is a most desirable consummation. The capital expenditure involved by the recommendations of the Commission amounts to nearly £3,000,000, a large proportion of which will find its way to this country if British engineers do not allow themselves to be forestalled by their Continental rivals.

An industry which has suddenly developed and spread to every part of the United States is the manufacture of cement or concrete blocks for building purposes. Some blocks are made solid, but hollow blocks are generally used with the object of saving cost and weight, and of insuring dry and warm walls. As the blocks are generally made from nine to twelve times the size of an ordinary brick, the cost of laying is materially reduced. American machinists have responded promptly to the demand, and are now producing moulding machines, by the aid of which the blocks can be turned out with great rapidity. The face of the block is formed at the bottom of the mould, thus enabling the operator to use a special mixture of material for the outer surface and to reproduce ornamental designs without extra expenditure. This new development of the cement industry is one that ought to be taken up in this country, a result that might be achieved by a little well directed energy on the part of cement manufacturers and makers of clayworking and brick machinery.

We regret to observe that the magnificent profits made last year by the Indian railways have been seized by the Finance Minister of the Government. This is an extremely foolish act, and one that, if made a precedent for future years, will indefinitely postpone the complete reorganisation and efficient development of the railway system. It is true that the budget for 1905-6 provides for a total expenditure of £8,333,333 on lines open, under construction, and projected; but analysis of the figures shows that the amount apportioned for rolling stock on lines open is less than in the year 1903-4, and there is ample evidence that the equipment is still very deficient. Again, although the Government make a great parade of the mileage in course of completion and to be undertaken, we must set off the fact that the collective length of the lines now open in India is only about half that which was considered to be necessary twenty years ago. It will be truly lamentable if the railway system of India should become

the prey of the Finance Department, as the Post Office has become the plaything of the Treasury in the Home Country.

In a previous issue* we described a method adopted with some success in the United States for rendering concrete water-tight by the application of boiled linseed oil. The chief objection to the use of oil for this purpose is that the treatment must be repeated at least once and sometimes twice every year. We now learn, on the authority of *Les Travaux Publics*, that a new preparation known as "Optimus" is capable of making concrete roofs or terraces perfectly water-tight for several years if a single application be made with due care. The composition is similar in appearance to volcanic asphalt, from which it is said to differ in certain important respects, and notably in that it will not soften or run, even when exposed to considerable heat. Before use it has to be melted in a suitable furnace, and is then applied by means of a brush, care being taken to see that the surface of the concrete is perfectly dry. We imagine this preparation consists largely of rock asphalt, but from the description given, it appears to be very suitable for the treatment of concrete, and far more likely to be satisfactory than a coat of drying oil.

In the proceedings of the American Society of Civil Engineers for April Mr. R. D. Coombs presents a series of designs and specifications for round-houses, and although not entirely new, these may be examined with advantage by railway engineers. The most interesting example is the design in which the whole construction is of concrete-steel, with the exception of the monitor-roof shown by the author in timber. This, of course, is not desirable, especially as the smoke-jack passes through the timber roof. Reinforced concrete is a most suitable material of construction for a round-house, where the fumes from locomotives are so injurious to unprotected steelwork, that, as the author says, from ten to fifteen years is probably the maximum life of the roof.

* Vol. ix., p. 552.

Considering the astounding manner in which all who have to do with the Port of London are still contriving to bar the way of progress by the jealous distrust which makes co-operation impossible, there is good reason for envying the more businesslike, as well as the more patriotic methods followed by other nations. In the agreement recently made by the Belgian Government and the municipality of Antwerp we have an object-lesson which ought to be taken to heart by our own administrative bodies from Imperial Parliament downwards. While we, the premier maritime nation of the world, cannot decide to spend a few million pounds for improving our greatest port, a little country like Belgium is going ahead with a project at an estimated cost of more than £10,000,000 for improving the docks at Antwerp. The works in question involve the construction of a ship canal 5 miles in length and enough new docks and quays to increase the accommodation to four times the present amount. This means still more serious foreign competition, and demands immediate action on the part of Government with regard to the Port of London.

Design of Concrete-Steel Beams.*

W. Noble Twelvetrees, M.I.Mech.E.

In steel and concrete we have two materials, of which the most prominent features are, respectively, strength and durability. The problem is to effect their combination in such manner that they may be employed to satisfy the requirements of scientific construction. The solution is to be looked for in the union of concrete and steel in such a way as to produce what is practically a new material, possessing the solidity that characterises masonry construction, while ensuring ample stability, strength and stiffness. Compliance with these conditions is rendered possible by combining the materials so as to form what is described by the generic term "concrete-steel," or reinforced concrete.

It is well known that the use of concrete alone is limited to classes of work where high compressive strength is one of the chief requirements, as the low tenacity of concrete makes it, like cast iron, an extremely uneconomical material of construction for many purposes.

Taking, as an example, the case of a concrete beam supported at the ends and loaded in the centre, we find the upper or compression side is capable of supporting at least ten times the load that would cause failure of the lower or tension side. This undesirable unequality of resistance can be adjusted by embedding steel so as to take the tension encountered in the lower portion of the beam, thus permitting the strength of the upper part to be fully utilised in supporting much greater loads than would otherwise be possible.

Adhesion of Concrete to Steel.—Adhesion of the concrete to the steel is a matter of prime importance, and without it the distinctive qualities of concrete-steel could not be realised. The high resistance of the combination is largely due to the fact that the constituent parts adhere so strongly one to the other that the action is that of a homogeneous structure. Adhesion enables the concrete to offer resistance against sliding along the surface of the steel, and thereby facilitates the transference of forces from one material to the other. The result is uniform behaviour somewhat akin to that obtained by the employment of iron or steel plates in the ordinary flitch-beam.

Various experiments have been carried out with the object of determining the adhesion of concrete to steel.

Dr. Ritter states the value to be from 568 lb. to 668 lb. per sq. in., and similar values are given by Professor Bauschinger.

The general practice of engineers on the Continent and in the United States is to adopt 570 lb. per sq. in. as the basis of calculation, but this is too high a value for plain rods or bars.

Function of the Reinforcement. — The primary function of the steel used as reinforcement is to resist tensile stress. It has also to resist shearing stress, and sometimes compressive stress. But an important function of the reinforcement is to insure the thorough distribution of strain in every part of the concrete in which it is embedded, thus preventing the concentration of strain and consequent rupture at any point where there may be an element of weakness.

Methods of Calculation.—Although it is the fact that concrete acquires greatly increased strength when combined with steel, a very usual practice is to allow nothing for the value of the concrete in the tension area of a beam, so far as concerns resistance to flexure.

The position of the neutral axis in a beam of simple concrete is affected by the fact that the compressive strength of the material is greater than its tensile strength, and as stress increases, the neutral axis moves away from the axis through the centre of gravity of the section.

Taking 10 : 1 as the ratio representing the compressive and tensile strength of concrete, it can be demonstrated by mathematics that the proportionate depths of the compression and tension areas in a rectan-

* Abstract of paper read before the Society of Civil and Mechanical Engineers, April, 1905.

gular beam of simple concrete will be about one-fourth and three-fourths of the depth of the beam, respectively.

By adding steel in the tension area to such an extent as to make the resistance of steel + concrete ten times greater than the resistance of concrete in the compression area, we should get the converse of the previous condition.

In one case the neutral axis would be near the top of the beam, and in the other near the bottom. Between these extremes any required variation may be effected by adjusting the relative resistance of the materials in the compression and tension areas. Thus the position of the neutral axis in a concrete-steel beam depends upon the proportions of concrete and steel, and upon the disposition of the steel with respect to the neutral axis.

The height of the neutral axis may be calculated for any beam after these details have been settled, and the proportions of concrete and steel may be adapted to any chosen position for the neutral axis.

The ordinary rule $f = \frac{3}{4}\ Wl \div bd^2$, for determining the stress in solid rectangular beams under uniformly distributed load does not differentiate between stress at the upper and lower fibres, and it follows that the results thereby obtained can only apply to the case of beams in which the neutral axis passes through the centre of gravity of the section.

When dealing with beams of concrete-steel, where in addition to the effects of differences in the resistance of concrete to tension and compression we have to consider the effects due to the quantity and disposition of the steel, the formula is absolutely useless, and some alternative method of calculation becomes necessary.

Formulæ derived from Beam Equations.—The bending moment (M) developed in any beam must always be resisted and held in equilibrium by the moment of resistance (R) of the section. Therefore, in every case the bending moment must be equal to the moment of resistance; or $M = R$.

For a uniformly distributed load on a beam, of the length l, supported at each end, $M = Wl \div 8$, and the general expression for the moment of resistance is $R = f\ I \div h$. As $I = bd^3 \div 12$ for a rectangular beam, and $d = (h + h)$, we get

$$R = fbh\tfrac{2}{3}h$$

where f = extreme fibre stress, at the distance h from the neutral axis; b = breadth of the beam section; and h = distance of the extreme fibres from the neutral axis.

Equating the expressions for M and R we have

$$\frac{Wl}{8} \times \frac{1}{fbh\frac{2}{3}h} = 1 \quad . \quad . \quad . \quad . \quad (1)$$

Whence

$$f = \frac{Wl}{5{\cdot}3bh^2} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and

$$W = \frac{5{\cdot}3fbh^2}{l} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Formula (2) gives the extreme fibre stress at the top or bottom of a rectangular beam, but in the case of a steel bar used as reinforcement in the tension area, the resistance of the concrete is usually neglected, and the stress is regarded as being concentrated at the centre of the bar. By eliminating the quantity bh from formulæ (2) and (3), and using F = total stress instead of f = intensity of extreme fibre stress, we should get

$$F = \frac{Wl}{5{\cdot}3h} \quad . \quad . \quad . \quad . \quad (4)$$

and for the load

$$W = \frac{5{\cdot}3\ Fh}{l} \quad . \quad . \quad . \quad . \quad (5)$$

But as the intensity of stress in a beam diminishes progressively from the extreme fibres towards the neutral axis, where its value = 0, the mean unit stress is $(f+0) \div 2 = \frac{1}{2}f$. Hence formula (4) gives double the correct value for the total stress F. and formula (5) gives half the correct value for the corresponding load W. Therefore the equations must be modified as below.

Denoting total tensile stress, considered to be concentrated at the centre of the reinforcement, by the symbol F_t'', and the distance from the neutral axis to the bottom surface by the symbol h_y, we have

$$F''_t = \tfrac{1}{2}\ \frac{Wl}{5{\cdot}3h_y} \quad . \quad . \quad . \quad . \quad (5)$$

and for the load

$$W = \frac{5{\cdot}3\ F''_t h_y}{l} \times 2 \quad . \quad . \quad . \quad (7)$$

If reinforcement be used in the compression area of a beam the total stress on the steel can be determined by the rule

$$F''_c = \tfrac{1}{2}\ \frac{(W - W')l}{5{\cdot}3h_x} \quad . \quad . \quad (8)$$

where F''_c = total compression stress on the steel, W' = calculated proportion of load carried by the concrete, and h_x = height of the compression area.

It is often the case that the centre of the reinforcement is not placed at the same distance from the neutral axis of the section as

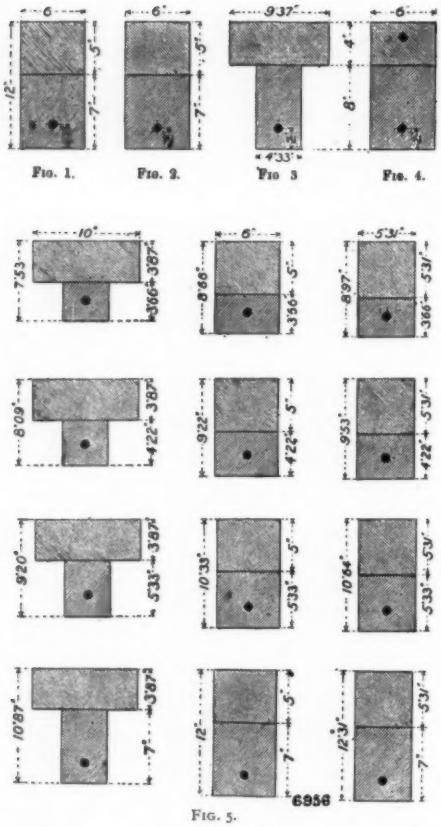


FIG. 1. FIG. 2. FIG 3 FIG. 4.

FIG. 5.

the theoretical centre of pressure of the tension stress area. For use under such circumstances, formula (6) must be modified by substituting the value of the actual distance between the centre of the reinforcement and the neutral axis.

$$\text{Thus} \qquad F''_t = \tfrac{1}{2}\frac{Wl}{8\,(h_y - z)} \quad . \quad . \quad . \quad . \quad (9)$$

Here z is the distance between the centre of the reinforcement and the bottom of the beam.

Total stress on the reinforcement in the compression area at any distance from the neutral axis other than $\frac{2}{3}h_x$, must be calculated by a modification of formula (8). Thus

$$F'' = \tfrac{1}{2}\frac{(W - W')l}{8\,(h_x - x)} \quad . \quad . \quad . \quad (10)$$

where x is the distance between the centre of the reinforcement and the top of the beam.

When the height of the compression area (without reinforcement) is known, the width of concrete section can be found for any load and span by an equation derived from formula (1).

Thus, denoting compressive fibre stress in the concrete by f'_c, and the distance from the neutral axis to the top surface by h_x, we have

$$b = \frac{Wl}{5{\cdot}3 f'_c h_x^2} \quad . \quad . \quad . \quad . \quad (11)$$

The foregoing rules assume the depth, load and span of the beam to be definitely fixed, and the height of the neutral axis to be known. In such cases they can be used to find the required areas of steel and concrete to comply with the stated conditions. But it is easy to derive equations equally available for determining the proportions of a beam to suit any load and span if the essential factors are known.

For instance, to calculate the height of the compression area from the load, span, and width of the section, and the unit stress of the concrete, we get from formula (1).

$$h_x{}^2 = \frac{Wl}{5{\cdot}3\,bf_c}, \text{ or } h_x = \sqrt{\frac{Wl}{5{\cdot}3\,bf_c}} \quad . \quad . \quad . \quad (12)$$

If the compression area is to be square in section we have

$$b^3 = bh^2 = \frac{Wl}{5{\cdot}3 f'_c}$$

$$\text{or } b = \sqrt[3]{\frac{Wl}{5{\cdot}3 f'_c}}, \quad . \quad . \quad . \quad . \quad (13)$$

In the tension area, the required distance of the reinforcement from the neutral axis will depend upon the area of steel used; and, conversely, the area of steel will be governed by its distance from the neutral axis.

Denoting this distance by the symbol h_y, we can determine the required value for any case by a modification of formula (9).

$$\text{Thus} \qquad h_y = \tfrac{1}{2}\frac{Wl}{8f''_t} \quad . \quad . \quad . \quad . \quad (14)$$

Where f''_t = permissible stress per sq. in. on steel in tension and a = area of steel in square inches.

To prove the accuracy of calculations made by the above formulæ, the resistance of each area may be calculated by a formula derived from the expression for the moment of resistance.

TABLE I.—CALCULATED PROPORTIONS OF CONCRETE-STEEL BEAMS.

(Uniformly Distributed Load, 4,000 lb. Span, 100 inches.)

Fig. No.	Dimensions of Cross Section of Beam. b.	Dimensions of Cross Section of Beam. d.	Height of neutral Axis above Bottom of Beam.	Height of Steel Axis above Bottom of Beam.	Area of Steel. No allowance made for Tension in Concrete.	Area of Steel. Allowing for Tension in Concrete.
	in.	in.	in.	in.	sq. in.	sq. in.
1	6	12	7	2·33	0·35	—
1	6	12	7	2·33	—	0·28
2	6	12	7	2·	0·33	—
2	6	12	7	2·	—	0·268
3	9·37* / 4·33	12	8	2·	0.27	—
3	9·37* / 4·33	12	8	2·	—	0·226
4	6	12	8	2·	0·27	0·206 / 0·30*

* Compression area.

Thus $R = F'_t (h_y - z) + (f'_m b h_x \frac{2}{3} h_x)$. (15)

The first term of this formula gives the resistance of the steel in tension, and the second the resistance of the concrete in compression. Here f'_m =mean stress per sq. in. on the concrete.

Table I. gives the width of concrete and area of steel as calculated by formulæ (3) (6) (8) (9) (10) and (11) for concrete-steel beams 12 in. deep with a clear span of 100 in., and under a uniformly distributed load of 4,000 lbs. The heights of the neutral axis and the steel axis were assumed, and the permissible fibre stresses were taken as follows:—

Steel in tension and compression, 15,000 lb. per sq. in.

Concrete in compression, 500 lb. per sq. in.

Concrete in tension, 50 lb. per sq. in.

The cross sections of the beams are represented in Figs. 1 to 4.

Table II. gives the height and width of the compression area, and the height of the tension area as calculated by formulæ (12) (13) and (14) for different areas of steel for concrete-steel beams with a clear span of 100 in., and under a uniformly distributed load of 4,000 lbs. The permissible fibre stresses have been taken at the same values as for Table I.

Fig. 5 shows various cross sections of beams based on the dimensions stated in columns 7 to 14 of Table II.

It will be understood that the width of the tension area need not necessarily be the full width of the compression area, the chief point for consideration being the provision of ample width.

Shearing Stresses.—The formulæ hitherto discussed are based on the assumption that

TABLE II.—CALCULATED PROPORTIONS OF CONCRETE-STEEL BEAMS.

(Uniformly Distributed Load, 4,000 lb. Span, 100 inches.)

Compression Area. Width.	Compression Area. Height.	Tension Area, height for Areas of Steel stated below. 1 sq. in.	¾ sq. in.	½ sq. in.	¼ sq. in.	Dimensions of Beam (b. × d.) for Areas of Steel stated below. 1 sq. in. b.	1 sq. in. d.	¾ sq. in. b.	¾ sq. in. d.	½ in. b.	½ in. d.	¼ sq. in. b.	¼ sq. in. d
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
10·	3·87	3·66	4·22	5·33	7·0	10·	7·53	10·	8·09	10·	9·20	10·	10·87
6·	5·					6·	8·66	6·	9·22	6·	10·33	6·	12·00
5·3	5·31					5·31	8·97	5·31	9·55	5·31	10·64	5·31	12·31

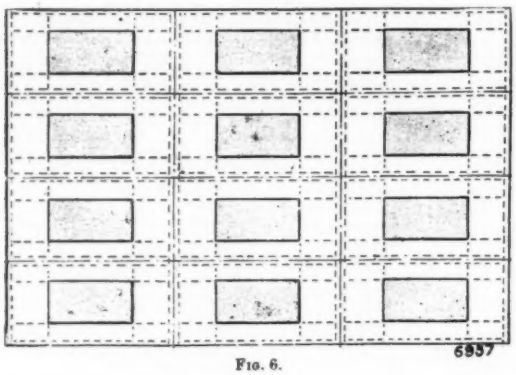


FIG. 6.

if sufficient steel be employed for resisting bending moments, shearing stresses may safely be left to the concrete. No doubt the concrete is perfectly capable of taking shearing stresses up to a certain limit, within which the safety of the beam may be fully assured, but greater strength is attainable by more complete conformity with theoretical requirements.

As the state of simple shear is one in which there are two principal stresses only, giving rise to a stress that is wholly tangential on any two planes inclined at 45 degrees to the axes of principal stress, and that is equal in intensity to the intensity of either of the principal stresses, it is evident that the reinforcement used for resisting shearing stresses should be perpendicular to the planes subject to normal stress. Further, as shearing stress in a beam, under a uniformly distributed load attains its maximum value at the supports and decreases in value towards the centre, the dimensions of the reinforcement may be diminished progressively towards the centre or alternatively,

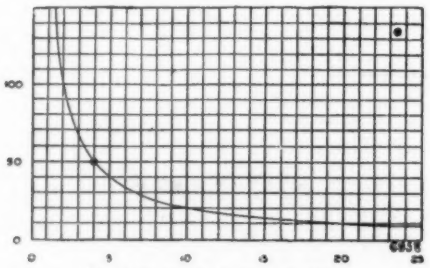


FIG. 7.—LENGTH OF SPAN IN FEET.

the spacing of the bars may be increased. The tension on diagonal planes in a beam can be calculated in a manner similar to that adopted in connection with the design of braced steel girders, and not be discussed in detail.

Floor Design. — A concrete steel floor system can be readily evolved from a collection of simple beam forms.

In the first place let us consider a beam in which the reinforcement in tension is such that, for the proper balancing of resistance, the concrete in compression must be extended in the form of a wide flange, giving a T-shape to the cross-section of the beam.

A little consideration will show that a very wide upper flange, whether of concrete alone, or of concrete with longitudinal rods, would be weak laterally, and might tend to crack or to break off from the main body of the beam. Hence, transverse reinforcement could be added with advantage.

The resulting beam would consequently be of T-section with longitudinal reinforcement near the bottom and a network of rods placed longitudinally and transversely, near the top.

It is evident, then, that the general proportions of the beam and the width of the compression flange can be varied at pleasure for a given load by corresponding adjustment of the reinforcement. The latitude so given is of considerable value in the design of flooring systems.

Let us take one floor panel, in which the main girders are 8 ft. apart, and the transverse girders, or joists, are 4 ft. apart.

We assume that, by suitable adjustment of the reinforcement, the compression flanges of the main girders have been made 4 ft. wide and say, 4 in. thick. Then, between the centres of two consecutive girders, spaced 8 ft. apart, there will be an interval of only 4 ft., as each of the compression flanges projects 2 ft.

Similarly, it is assumed that the top flanges of the joists are made 2 ft. wide. Consequently the interval between successive joists will only be 2 ft., as the compression flanges of the joists account for the other 2 ft. of the distance.

As shown in Fig. 6, the general result is that the assumed floor panel is complete, with the exception of a series of rectangular spaces, such as those represented by the shaded areas in the diagram, each space

measuring 4 ft. by 2 ft. These spaces can be filled in with concrete 4 in. thick, and the floor is thereby finished.

It will be understood that in practice the spaces would be closed concurrently with the formation of the top flanges of the girders and joists. Practically, therefore, the whole of the floor slab forms the compression flange of the connected system of beams.

Further, assuming the top flanges to be reinforced by longitudinal and transverse rods, it is a natural step to conclude that all these rods should be laid continuously from end to end of the span, and from side to side in the width of each panel.

The additional cost of the metal would be quite inconsiderable, and the cost of labour would probably be reduced because the rods would not have to be cut, and the number of separate pieces would be smaller. These rods would then occur at predetermined intervals in the flanges of the girders and joists, and would also continue across the concrete filling the parts of the floor system not covered by the previously defined widths of the flanges.

Here we have an additional feature of strength due to the reinforcement of the whole of the floor slab by steel rods running in two directions, and thus binding the construction still more firmly together.

It will be seen that in a floor designed in the manner here outlined, each of the joists acts as a stiffener for the flanges of the adjoining girders, and that the entire structure is so interconnected that an exact calculation of its strength is practically impossible.

But we have a further element of strength arising from the action of the various spans after the manner of continuous beams.

Again, interior arching effect, due to the action of adjoining floor pannels, adds about one-third to the area of the compressive stress diagram, the additional compression being taken up by adjoining floor panels, instead of by the reinforcement.

Something may also be allowed for the arching effect produced by a uniformly distributed load. It must be borne in mind, however, that no allowance for arching effect should be made in the case of loads that are liable to "flow" like corn and other loose materials.

The arching action necessarily varies with the reflection and with the details of design, but the result of practical experience is to show that the increased resistance thereby given to a span of 4 ft. may be generally stated at 50 per cent.

Fig. 7 is a diagram prepared by Mr. A. L.

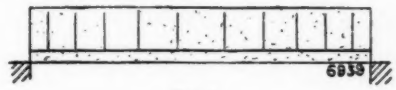


FIG. 8.

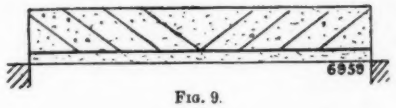


FIG. 9.

FIG. 10.

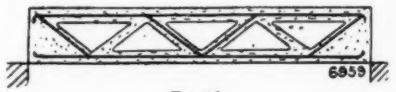


FIG. 11.

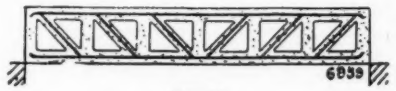


FIG. 12.

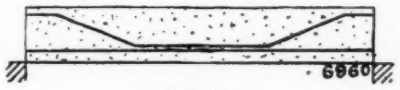


FIG. 13.

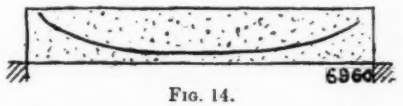


FIG. 14.

FIG. 15

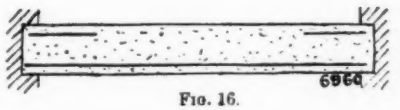


FIG. 16.

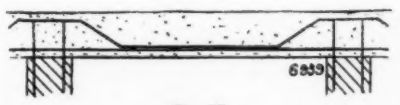


FIG. 17

Johnson, and reproduced from the Proceedings of the American Society of Civil Engineers. From this the percentage for a span of any length up to 25 ft. can be read off.

We now have the following simple method of determining the proportions of beams used in floor construction:

1. Calculate the values of the moments of resistance by the rule previously stated for simple beams.

2. Double the values so obtained, to allow for continuous girder action and the arching action of adjoining floor panels.

Add a percentage from Fig. 7 corresponding with the length of span to allow for arching effect caused by a uniformly distributed load.

Typical Forms of Beam Design.—The simplest possible form for a supported concrete-steel beam is one having horizontal reinforcement consisting of one or more bars placed near the bottom of the beam, for resisting tensile stress. Compressive and shearing stresses are taken by the concrete without assistance.

In Fig. 8 a similar beam is represented, but shearing stress is here resisted wholly or in part by vertical ties or stirrups. The auxiliary reinforcement can be formed of round rods, or of flat strips of steel, as may be preferred.

In Fig. 9 the main reinforcement is the same as before, but the auxiliary reinforcement is placed diagonally, for reasons that have been discussed before.

In Fig. 10 we have a suggested method of applying expanded metal for taking stresses arising from shear. The metal can be applied in the form of separate sheets. the lower edges wrapped round the outer rod of the reinforcement on each side of the beam, or in the form of a trough, the bottom of which would lie under the longitudinal reinforcing rods. In the latter arrangement a considerable part of the tension due to bending moment would be carried by the expanded metal. The main reinforcement is disposed similarly to that in previous examples.

In large beams, where the amount of metal might form a considerable item of expenditure, the proper course for adoption would be to employ two or more troughs of varying length and fitted one inside the other, so as to give the required graduation of resisting power, somewhat after the manner in which engineers graduate the plates of a built up girder.

In Fig. 11 the beam is designed on the principle of the "Warren" girder. Both the top and the bottom flanges are reinforced, the latter with more metal than the former; the diagonal web members in tension are reinforced, but the diagonals in compression rely upon the concrete for the necessary resistance. This beam is a framed structure, consisting of clearly defined flanges and diagonals as shown in the drawing.

In Fig. 12 is shown another type of framed beam designed on the principle of the Linville truss, and it should be noted that the spacing of the tension members of the web is one half that of similar members in the "Warren" type.

In Fig. 13 we have longitudinal horizontal reinforcement, consisting of one or more bars near the bottom of the beam, and additional reinforcement consisting of one or more bars bent in an upward direction near the supports. The horizontal part of the latter reinforcement is shown above the first mentioned bars for the sake of clearness, but in practice it is usually situated in the same horizontal plane. The concrete, acting in conjunction with the steel bars, practically forms a trapezoidal or queen-post truss. This type of construction is most suitable for beam with fixed ends and for continuous beams.

In Fig. 14 we approach another method of reinforcing concrete beams, in which the reinforcement is shown bent into a curve similar to that forming one boundary of the bending moment diagram of a supported beam under a uniformly distributed load. Although theoretically correct so far as bending moment is concerned, this arrangement does not lend itself conveniently to the application of ties for resisting shearing stress, and in practice it will be found to involve more expense and trouble than the use of other forms of reinforcement.

In Fig. 15 the last mentioned system is shown in connection with a beam having its ends firmly fixed in the walls of a building.

In Fig. 16 is shown another system of reinforcement, providing in a very simple manner for the incidence of tensile stress in a beam fixed at the ends, and although this mode of treatment does not conform so closely with theoretical requirements as the method described above, it can be applied easily and cheaply.

In Fig. 17 we have part of a continuous beam, where the conditions generally resemble those in a beam with fixed ends, and in this diagram vertical reinforcement is shown in the supports, connected to the bent ends of the bars, serving to resist tension up to the points of contrary flexure

and afterwards in the central portion of the beam.

A further modification of design is suggested by the application of the tubular system to beam construction. In this way the usefulness of a specified quantity of concrete can be increased, or for a specified duty the quantity of concrete can be reduced.

The area of concrete removed, below the neutral axis, would have been of comparatively little value for resisting tension, and if, as usual, the tensile strength of concrete is not taken into account, the theoretical loss is nothing.

Water Hammer.

THE question of water hammer or hydraulic shock caused by stopping the flow in a water pipe is of great practical importance, as such shocks frequently cause the pipe to burst. Water hammer has been well defined as follows: * "When a liquid is flowing through a pipe there is a certain amount of energy in the liquid, and if you stop the flow this energy must be used in some way. If the liquid is incompressible and you stop the flow suddenly, the energy of the liquid is used up in doing work on the pipe by stretching it or increasing its diameter. If the liquid is compressible the energy of the liquid is used up in compressing the liquid and stretching the pipe. Nearly all bursting of pipes is due to a sudden checking of the velocity of or to the freezing of the liquid."

Although the phenomenon has long been known, its nature has not been thoroughly understood or explained until recently. Previous explanations were little better than guesses, and the effects upon the pipe could neither be foreseen nor avoided. Experiments upon a sufficient scale have been lacking, and up to as late as 1897 and 1898, when the subject was taken up by the American Society of Civil Engineers, the results of the discussion went to show that existing data were insufficient and that more experiments were necessary. Since that time more satisfactory experiments have been made in connection with a general mathematical study of the problem, and formulæ governing the phenomenon have been established and experimentally proved to be correct. The experiments referred to were carried out upon a large scale in Moscow as a result of the establishment of the new waterworks in that town, when the question came up as to the velocities which could be safely allowed in water pipes of small diameter. They were carried out during 1897-98 under the charge of Professor Joukovsky, of the Moscow University and the Moscow Imperial Technical Institute, who issued a report which has subsequently been dealt with in a paper by Mr. O. Simon, presented to the American Water Works Association.* Professor Joukovsky gives a complete analytical explanation of the phenomenon of water hammer in all its phases. His method of reasoning is purely mathematical and deductive. Starting from a general differential equation given by Riemann, Joukovsky explains all cases of water hammer by the transmission of a pressure wave in the water pipe and by its reflection from the ends of the pipe. In the analytical determination of the velocity of transmission of this pressure wave, he deduces a formula which fully agrees with that given by Korteveg, of Leyden (1878), for the transmission of sound in an elastic pipe filled with a compressible liquid. Joukovsky showed that Korteveg's formula applies to water hammer in pipes. In cases of water hammer a very rapid oscillation of pressure results, the pressure rising above the normal, then falling below the normal and again rising, and so on, the amplitude of the vibrations gradually diminishing until the normal pressure is again established. In his experiments Joukovsky used Crosby indicators, each with a very rapidly moving ribbon of paper upon which pressure diagrams on a large scale were traced giving a detailed record of the pressure oscillations. These diagrams show that the time from the beginning of the rise of pressure above the normal to the beginning of the fall below the normal is the same for all points of the same pipe. He found that this time is equal to that required for the wave with velocity λ calculated theoretically and verified experimentally to travel from the gate to the origin and back. At the gate the transition from supernormal to subnormal pressure, or *vice versâ*, is not interrupted by any period of normal pressure, but at all other points in the pipe such periods of normal pressure intervene resulting in the diagrams being stepped. The formula for the velocity λ of propagation for the pressure wave, as deduced by Joukovsky, is as follows;

$$\lambda = \frac{1}{\sqrt{\frac{\gamma}{Kg} + \frac{2 R_0 \gamma}{eEg}}\sqrt{\frac{\rho_0}{K} + \frac{2 R_0 \rho_0}{eE}}} = \frac{1}{\sqrt{\frac{\gamma}{Kg} + \frac{2 R_0 \gamma}{eEg}}\sqrt{\frac{\rho_0}{K} + \frac{2 R_0 \rho_0}{eE}}},$$

* G. M. Peck, Trans. Am. Soc. M.E., Vol. XXI.

* Proc. 1904, pp. 341—420.

where

$2R_0$ = the diameter of the pipe.
e = the thickness of the walls of the pipe.
E = Young's linear modulus of elasticity of the material of the pipe.
$= \frac{\text{unit stress}}{\text{unit stretch}}$.
= 1,000,000 kilograms per square centimeter for cast iron.
= 10^{10} kilograms per square meter for cast iron.
K = the volumnar modulus of elasticity of water.
= 21,000 atmospheres.
= 300,000 pounds per square inch.
γ = the weight of a unit of volume of water.
g = the acceleration of gravity.
$\rho_0 = \frac{\gamma}{g}$ = the density (mass per unit of volume) of water.

As already mentioned, this formula for the velocity of the pressure wave fully coincides with Korteveg's formula for the volocity of sound waves in an elastic pipe filled with a compressible liquid.

Korteveg's formula is:

$$\lambda = \frac{\lambda_1 \lambda_2}{\sqrt{\lambda_1^2 + \lambda_2^2}} ,$$

where

λ_1 = the velocity of the sound wave in an inelastic pipe filled with a compressible liquid.

This velocity is

$$\lambda_1 = \sqrt{\frac{Kg}{\gamma}} = \sqrt{\frac{K}{\rho_0}} .$$

For water, λ_1 = 1,435 meters per second = 4,711 feet per second.

λ_2 is the velocity of the pressure wave in an elastic pipe filled with an incompressible liquid. This velocity, as given by Resal in discussing the pulsation of the blood in the arteries of animals, is

$$\lambda_2 = \sqrt{\frac{eE}{2R_0\rho_0}} = \sqrt{\frac{eEg}{2R_0\gamma}} .$$

Substituting these values of λ_1 and λ_2 in the formula of Korteveg, we obtain exactly the formula deduced by Joukovsky for the velocity of the pressure wave in an elastic pipe filled with an elastic liquid.

Applying this formula, Joukovsky calculated the theoretical value of λ for the pipes used in his experiments, obtaining the values given in the following table, in which all the steps of the calculation are shown.

The formulæ of Joukovsky being entirely rational, and not empirical, any system of units may be used at pleasure, care being taken, of course, to adhere to one and the same system of units throughout any one equation.

TABLE I.

Table of Theoretical Calculation of λ.

Diameter of the Pipe. Inches.	Thickness of Walls of Pipe. Inch.	λ Feet per Second.	
		Calculated.	Obtained Experimentally.
2	$\frac{1}{12}$	4424	4375
4	$\frac{1}{12}$	4228	4200
6	$\frac{1}{12}$	4116	4100
24	$\frac{1}{12}$	2996	3313

Joukovsky also found a formula for the maximum additional pressure E produced by the closure of the gate which is

$$P = \frac{v\lambda\gamma}{g} = v\lambda\rho_0,$$

where

v = the extinguished velocity of water in the pipe.
λ = the speed of propagation of the pressure wave in the pipe.
γ = the weight of a unit volume of water.
g = the acceleration of gravity.
$\rho_0 = \frac{\gamma}{g}$ = mass of unit of volume of water — its density.

From this formula it will be seen that the increased speed of pressure stands in direct proportion to the extinguished velocity V of flow; that it does not depend upon the length of the pipe, and that it is directly proportional to the velocity L of propagation of the pressure wave, L being expressed by the formula given above. This quantity depends on the size, thickness, and kind of pipe, and on the density and modulus of elasticity of the liquid.

Substituting numerical values in the formula

$$P = hv = \frac{v\lambda\gamma}{g}$$

Joukovsky finds that, for the pipes with which he experimented, each foot per second of extinguished velocity of flow causes an increase of pressure as given in atmospheres in the following table:

TABLE II.

Theoretical Values of Additional Shock Pressure.

$2R_0$ Diameter of Pipes, in Inches.	$h = \frac{P}{v}$ Additional Pressure, per Foot per Second of Extinguished Velocity of Flow, in Atmospheres.
2	4·066
4	3·886
6	3·783
24	2·754

From this table it will be seen that for pipes of small diameters the increase H of pressure for each foot of extinguished velocity of flow V equals about four atmospheres.

The paper proceeds to deal with the experimental proofs of the correctness of Joukovsky's theory, which was obtained as follows: 1. The measurement by means of Bourdon manometers of the maximum additional shock pressure. 2. The measurement by means of Marey chronograph of the velocity of pressure waves propagation. 3. The determination from Crosby indicator diagrams of the pressure wave velocity and of the shock pressure.

The concluding portion of the paper deals with the miscellaneous phenomena connected with water hammer, as *e.g.*, 1. Reflection of the pressure wave from a dead end. 2. From an open end. 3. Influence of slow closure of the gate. 4. Efficiency of air chambers. 5. Efficiency of safety valves. 6. Location of air pockets by means of the indicator diagram. 7. Location of leaks by similar means.

The paper concludes with a summary of the results obtained, which are as follows:

1. The shock pressure is transmitted through the pipe with a constant velocity, which seems to be independent of the intensity of the shock. This velocity depends upon the elasticity of the material of the pipes and upon the ratio of the thickness of their walls to the diameter. Ordinarily, in cast-iron pipes the ratio of thickness to diameter decreases somewhat with increase of the diameter; hence the velocity of the pressure wave is a little less, in pipes of large diameters, than in pipes of smaller diameters. For pipes of diameters from 2 to 6 in. this velocity is about 4200 ft. per second; for 24-in. pipes it is about 3290 ft. per second.

The speed of propagation of the pressure wave remains the same, whether the shock is caused by arresting the flow of a column of water moving in a pipe, or by suddenly changing the pressure in the column of water (flowing or standing) in any part and by any other means.

2. The shock pressure is transmitted along the pipe with a constant intensity. The shock pressure is proportional to the destroyed velocity of flow and to the speed of propagation of the pressure wave. For ordinary cast-iron pipes, of diameters from 2 to 6 in., the increase of pressure, for every foot per second of extinguished velocity of flow, is about four atmospheres, and, for a 24-in. pipe, about three atmospheres.

3. The phenomenon of periodical vibration of the shock pressure is completely explained by the reflection of the pressure wave from the ends of the pipe, *i.e.*, from the gate and from the origin.

4. If the water column continues flowing, such flow exerts no noticeable influence upon the shock pressure. In a pipe from which water is flowing the pressure wave is reflected from the open end of the pipe, in the same way as from a reservoir with constant pressure.

5. A dangerous increase of shock pressure occurs when the pressure wave passes from a pipe into another of smaller diameter with a dead end. In this case the shock pressure is doubled when the wave reaches the dead end. Where there are several branches, one from another, this doubling may take place several times and these doubled pressures accumulate, so that, under unfavourable conditions, the pressure may become very great.

6. The simplest method of protecting water pipes from water hammer is found in the use of slow-closing gates. The duration of closure should be proportional to the length of the pipe line. Air chambers, of adequate size, placed near the valves and gates, eliminate almost entirely the hydraulic shock, and do not allow the pressure wave to pass through them; but they must be very large, and it is difficult to keep them supplied with air. Safety valves allow to pass through them pressure waves of only such intensity as corresponds to the elasticity of the springs of the safety valves.

7. The diagram of the shock pressure enables us to determine the location and extent of air pockets. They serve also for the location of leaks, and generally for a study of the condition of the pipe line.

Measuring Angular Velocity of Engines.

THE following method will be found superior, in many respects, to the well-known tuning-fork method for measuring the variations in speed during the different parts of a revolution, or cycle, of an engine. The method affords an exact determination of the distance travelled in certain chosen intervals of time by the periphery of the fly-wheel of the engine, and therefore necessitates the use of a mechanism for denoting the distance and for gauging the time.

The essential apparatus* consists of a

* *Electrical World and Engineer*, New York.

miniature motor which may be run at a constant speed of a sufficiently high value from any available source of current. The motor should be placed with its shaft perpendicular to that of the main engine, as shown in Fig. 1. On the motor shaft should be fitted a small pulley, indicated as P, to which is joined a wiping bristle, B, for the purpose of marking off the distances travelled by the periphery of the fly-wheel during one revolution of the motor. The motor should be mounted on a slider, substantially as illustrated, with its edges parallel to the face of the pulley and arranged to move freely in the guides. A tracer of wire, shown as T in Fig. 1, serves for making a line, L_1, on the chalked surface of the pulley when it revolves. This line is of assistance in forming a more or less regular spiral, upon which the distances corresponding to the angular velocities are marked off by the wiper on the shaft of the motor.

After the face of the pulley of the engine has been thoroughly rubbed with chalk and the auxiliary apparatus has been placed as indicated in the drawing, the armature of the motor should be connected to a source of current of such a nature that it will make one mark on the face of the pulley for every six or eight inches of periphery of the fly-wheel of the engine. When the conditions are proper for a record, and the motor is running steadily at the desired speed, the slider, S, should be moved by hand at such a rate as to obtain as many spiral lines as possible across the face of the pulley without confusing the cross marks, M, made for each revolution of the motor. The combinations of the spiral line and the cross marks form the record of the speed variations of the engine.

When the engine is stationary, a zero point with reference to the position of the fly-wheel may be found by setting the crank accurately on the dead centre and moving the slider so that the wire, B, will make a mark, D, across the face of the pulley. The distances between the consecutive intersections on the spiral line may conveniently be plotted as ordinates on cross-section paper, with abscissæ corresponding to the number of spaces on the spiral line. The ordinates evidently correspond to the different velocities of the fly-wheel at different times, and from these ordinates may be calculated the percentage variation in speed.

Messrs. Ryan and Kochendorfer, senior electrical engineers at the University of Minnesota, have recently applied the above method in tests on a number of gas engines especially constructed for driving dynamos. The curve shown in Fig. 2 was taken by them during a test on a direct-connected unit, consisting of a four-cycle, single-cylinder gas engine and a 125-volt, direct-current generator.

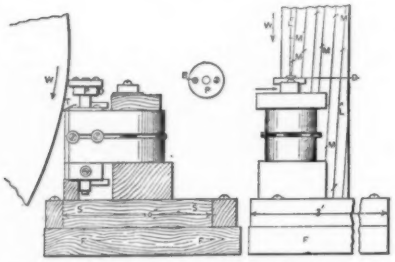


FIG. 1.—SIDE AND END VIEWS OF MAGNETO MOTOR AND MOUNTINGS.

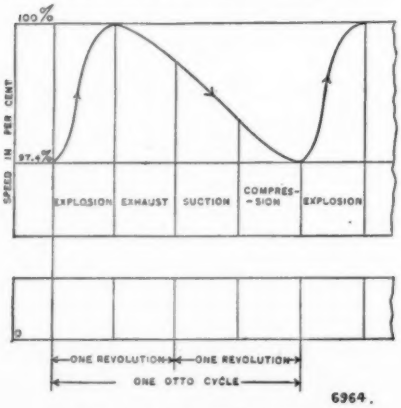


FIG. 2.—SPEED CURVE OF GAS ENGINES.

Wind Gauge and Recorder on the Furness Railway.

It will be remembered that an extraordinary accident occurred some time ago at the Levens viaduct on the Furness Railway. During a violent gale, a train standing on the viaduct was actually blown over on its side. To avoid the possibility of any similar accident occurring in the future, an apparatus was installed which fulfils the duties of a watchman over the weather, and warns the signalman at each end of the viaduct if the wind should be blowing with a force sufficient to render

the passing of a train over the viaduct dangerous. The following is a description of the apparatus as given by *The Electrician :*

The recorder is mounted in a frame built up of steel angles (Fig. 1); on two sides of the frame boards are carried on hinges and are kept nominally in the vertical position by means of springs, which are similar in construction to those used in ordinary steam engine indicators. The strength of the spring is so reckoned out in relation to the area of the board that a given pressure of so many pounds per square foot can be recorded on the paper chart which is moved by the clock of the recording instrument at the rate of 1 in. per hour. Two pens are fitted—one being controlled by each board. If the pressure on either board remains constant then the pen will continue to draw a straight line, but an increase or a decrease of pressure will give a deviation of the line at a point on the paper corresponding to the time that this change of pressure takes place. To ensure proper working periodical tests are made, and a lever equivalent to 32 lb. weight is tried on the gauge each time the lineman visits the instrument, so as to ascertain that all is in good order. The recording instrument was supplied by Messrs. Elliott Bros.

In connection with the recorder is an electric bell circuit, so arranged that the batteries at the two signal boxes at either end of the viaduct are in opposition until the pressure of wind blowing at right angles to the viaduct rises to 32 lb. per square foot, at which pressure contact is made at a point marked 'A' in Fig. 2. The current from both batteries then flows, the relay armatures are drawn up, local batteries come into play, and the warning bells ring and continue to do so as long as the force of the wind is dangerous—that is, equal to or exceeding 32 lb. pressure per square foot.

Since the erection of the apparatus more than 18 months ago, on no occasion has the wind exceeded a pressure of 5 lb. per square foot. The installation was erected by the railway company's electrical engineers, Messrs. J. B. Saunders & Co., of Westminster.

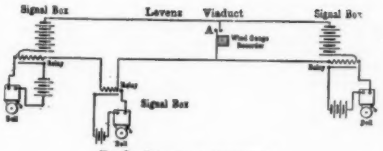


FIG. 2.—DIAGRAM OF CONNECTIONS.

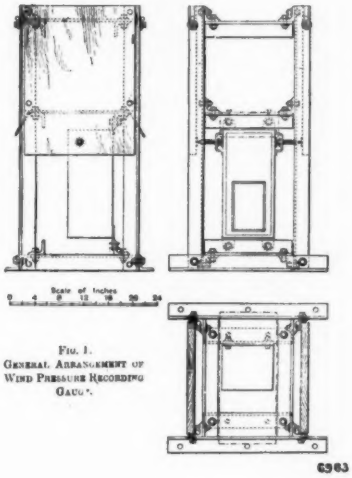


FIG. 1.
GENERAL ARRANGEMENT OF WIND PRESSURE RECORDING GAUGE.

6963

Automobile Compressed Air Carpet Cleaning Plant.

THE accompanying illustration is that of a novel form of motor vehicle fitted with a compressed air plant for carpet cleaning purposes. It has recently been constructed for use in South Wales by Tilghman's Patent Sand Blast Co., Ltd., Broadheath. The photograph was taken with the panelling removed, to show the disposition of the machinery. A Gardner petrol motor, rated at 20 B.H.P. at 600 revolutions per minute, supplies power for compressing 110 cubic ft. of free air per minute to a pressure of 60 lbs. per sq. in. when driving the compressor, or, when propelling the vehicle, to develop a minimum speed of 3 miles per hour on a gradient of 1 in 9.

The Air Compressor is of the vertical double cylinder single-acting type, having water-cooled cylinders 9 in. diameter by 6 in. stroke, and designed to run at 300 revolutions per minute and to compress the quantity of air mentioned above. It is driven from the engine crank shaft by means of a raw hide pinion and spur wheel. The crank shaft of the compressor is 2½ in. diameter, and the bearings, all of which have large wearing surfaces, are lubricated on the splash system from the oil bath in the crank case.

The air receiver, which is 4 ft. long by 18 in. diameter, is built of steel plate with pressed steel ends, and fitted with pressure gauge, safety valve, &c. The receiver is placed under the driver's seat.

The air pipe from the compressor to the receiver is carried round the frame work of the vehicle before reaching the receiver, so that any water entrained with the air after compression can be separated.

The water-cooling tank is coupled to both engine and compressor, the connection being so arranged that the water can be run through the engine only, or through both engine and compressor, as required. This tank is placed behind the rear axle, and securely bolted to the framework.

The frame work of the lorry is of steel channel-iron, 6 in. by 3 in., weighing 16 lbs. per foot, strongly braced together and rivetted.

The road wheels are built entirely of steel, the bosses being bushed with gun metal.

The axles are mild steel forgings connected to the framework by grasshopper springs of the ordinary pattern, and the rear axle is stayed from the countershaft bearings by two radius rods.

The change speed gear box is arranged under the frame of the lurry, and is designed to give forward speed of 3 to 6 miles per hour and a backward speed of 3 miles per hour. It also contains the differential gear which drives the countershaft, the smallest diameter of which is 2¼ inches. All the gears are of steel, machine cut from the solid, and they are arranged to run in oil continuously.

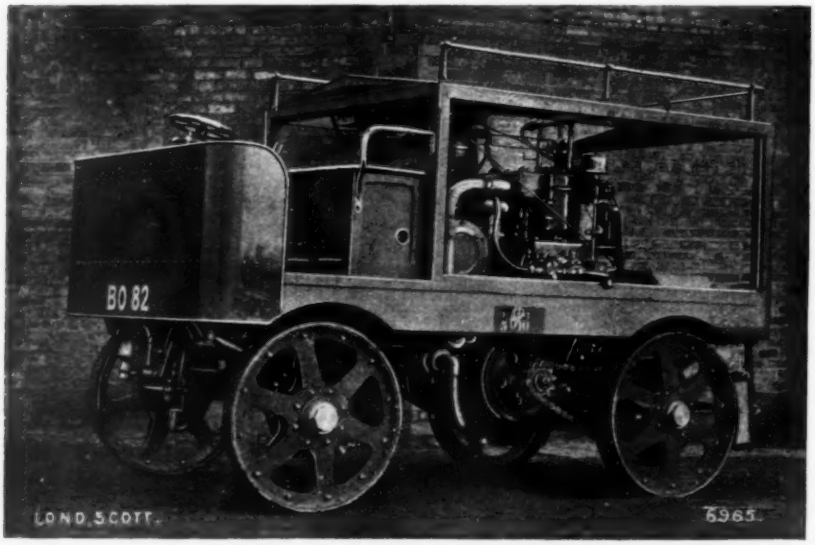
The motion is transmitted from the engine to the gear box through three steel wheels and from the countershaft to the road wheels through two roller chains of 2 in. pitch, each chain having a breaking strain of 30,000 lbs.

The wooden framework and roof round the engine and compressor is arranged to receive wooden panels, any of which may be removed singly for getting at the machinery.

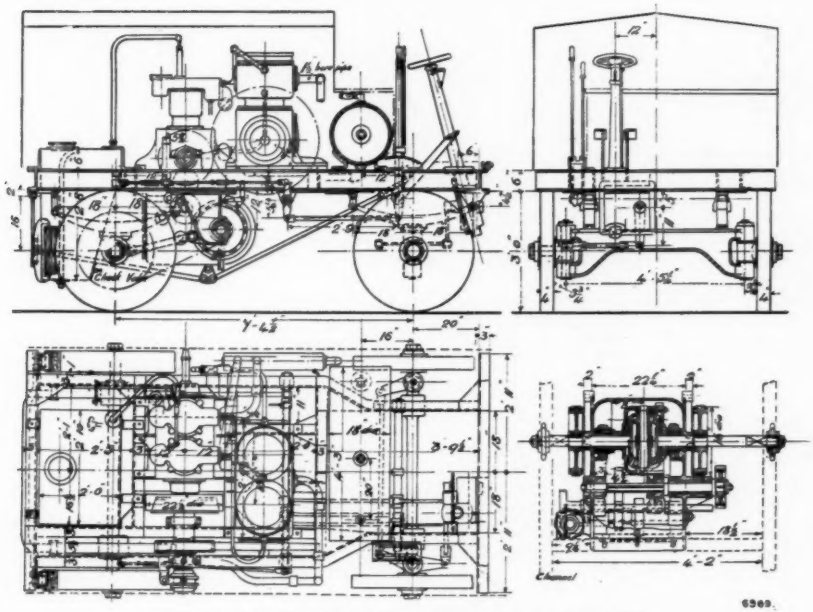
The petrol tank is secured to the framework inside the engine room in position for easily filling from the driver's seat.

Two independent brakes are provided, one operating on the two rear wheels through wooden brake blocks, and the other operating on two band brakes operating on countershaft.

The steering gear consists of strongly designed linkwork, manipulated from the



COMPRESSED AIR AUTOMOBILE CARPET-CLEANING PLANT.



DETAILS OF COMPRESSED AIR AUTOMOBILE CARPET-CLEANING PLANT.

steering wheel through a worm and worm-wheel, this arrangement making the steering handle self-locking in all positions.

The Design of the Antarctic Exploration Vessel "Discovery."

THE return from a long and successful voyage of the Antarctic exploration vessel *Discovery* rendered appropriate the placing on record at the recent spring meeting of the Institution of Naval Architects the special features of her design, and of the details of her construction. This was undertaken by the designer, Mr. W. E. Smith, C.B., in an interesting paper containing full specifications, and accompanied by complete drawings, the whole affording sufficient information to enable a naval architect to construct a similar vessel, or to make improvements thereon if the occasion arises in the future. The paper and specification fully explain the details adopted in the design, but it may be of interest to describe some of the special features thereof. The vessel, which was built by the Dundee Shipbuilding Company, is a single-screw wood ship of the following dimensions;—

	Ft.	In.
Length on the water line from fore edge of stem to axis of rudder...	172	0
Breadth, extreme	34	0
Depth amidships from top of ceiling to top of upper deck beam...	18	6
Mean draught to water line shown on the sheer drawing...	16	0
Displacement in tons to this water line (about)	1620	

The framing was arranged generally as shown on the midship section, the bow being fortified by shores as in whalers, and the stern specially strengthened.

Form of Stern.—Preceding British vessels engaged in Polar exploration, and also whalers, had the old wooden frigate form of square counter stern so long current in the British Royal Navy. This seemed to the designer not the best form of stern for the work, and on his representation the Ship Committee consented to adopt a form of stern which, to a less pronounced extent, had been in vogue in the British Navy in the smaller classes of gunboats, and had

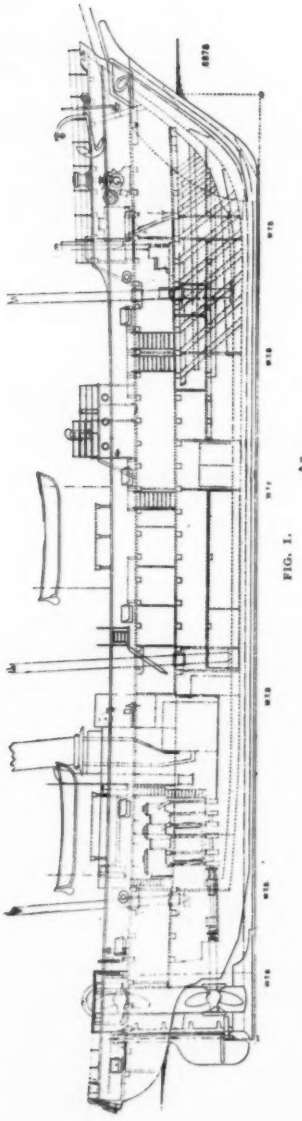


FIG. 1.

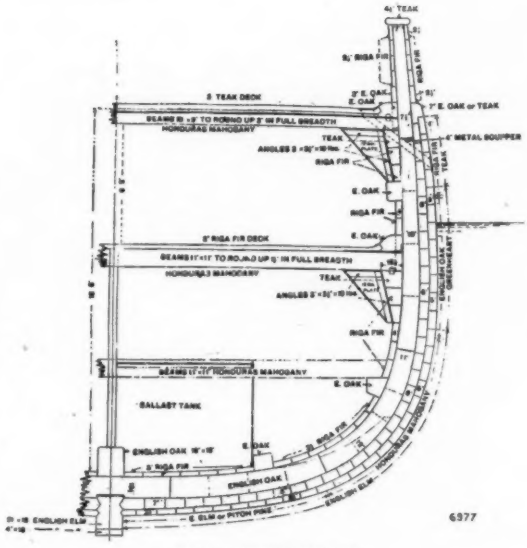


FIG. 2.—MIDSHIP SECTION.

given great satisfaction. This pronounced overhanging rounded form of stern was evidently of great advantage in ice work as compared with the older form of stern as it gave much better protection to the rudder, rudder post and screw than did the old form of stern and this feature was abundantly illustrated when the vessel got into the ice. Mr. Smith was of opinion also that in the case of the new *Discovery*, practically a sailing ship, where the helmsman had of necessity to be right aft in order that he might keep his eye on the sails, this form of stern would be more satisfactory in heavy seas, and that the helmsman would be drier and would soon see that he was better circumstanced and less likely to be exposed to a green sea in heavy Antarctic gales than in a vessel with the old form of stern. This form of stern was ultimately decided upon, and although it met with much adverse criticism at Dundee on the part of the experienced captains of Dundee whalers, all of whom had been used to the old form of stern, Captain Scott, after experience on actual service, wrote as under on this point:—

"The shape of the stern is excellent. In the heaviest following seas it rises quietly and naturally and without risk of pooping as long as the ship has way on. This is the greatest relief

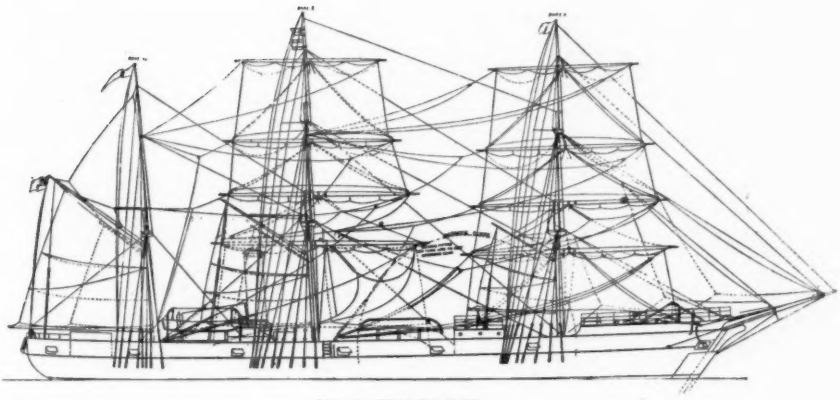


FIG. 3.—RIGGING PLAN.

to me; there is no more demoralising circumstance for a helmsman in bad weather than the chance of being pooped. In the chance of the wind failing suddenly in a heavy following sea there is a possibility of water coming over the stern, but this is most improbable, and as it is, our helmsmen have always dry quarters. A corresponding disadvantage of this form of stern is, of course, that in a heavy sea with no way on there is much more noise set up by the falling of the stern on a wave than is the case with the older form, but the balance of advantage lies strongly in the direction of dryness and safety even at the expense of some noise. The ship behaved excellently in an ordinary sea way. She is buoyant, very easy in motion, and exceedingly comfortable. In the Bay of Biscay the maximum roll recorded was 30 degrees, but this was to leeward; under sail the vessel had an average heel of 8 degrees."

Bilge Keels. The question of whether the vessel should, or should not, be fitted with bilge keels came under consideration. It was recognised that bilge keels would add largely to the comfort of those on board, but after full consideration, it was decided that, as bilge keels would very much add to the risk of the vessel getting entangled in ice, and to the danger of her remaining fixed in it if she were once entangled, they should not be fitted.

Captain Scott and his officers fully recognised this feature, and made no complaints with respect to the increased rolling due thereto; but the designer is of opinion it is well worth considering, on the part of any future expedition, whether it is not practicable to fit bilge keels in some easily detachable and attachable manner, so as to secure greater comfort when out of the way of the ice and no danger of entanglement when in the ice.

The entangling effect of any projection on the bottom is well illustrated by the fact that the ice gradually settled on the slight projecting fortification of the keel under the screw aperture, and altered the trim of the ship by 3 ft. On being released by the last charge of gun-cotton the stern of the vessel rose with a jump, and she recovered her normal trim.

Rudder—Method of Lifting and Securing. Anyone who has experienced the difficulty of shipping an ordinary boat's rudder when afloat with any sea on, will know how difficult it sometimes is to properly engage the pintles and braces. It is often a necessity to unship the rudder of a Polar exploration ship to secure its safety, and it becomes an equal necessity to ship it again thereafter to bring it into use. The method adopted in the *Discovery* was as shown in Fig. 4. This method was very effective. No skill of any sort was needed on the part of the operators, the rudder was simply entered into the rudder aperture and lowered into place, when it automatically felt its way into the brace.

A spare rudder, which did not depend on the lower pintle, and which would be quite efficient in the event of the carrying away of the rudder post, was provided as part of the equipment; but, although this spare rudder was used for a short time whilst the main rudder was under repair, the rudder post remained intact throughout the voyage, and the main rudder was, therefore, in use nearly the whole of the time.

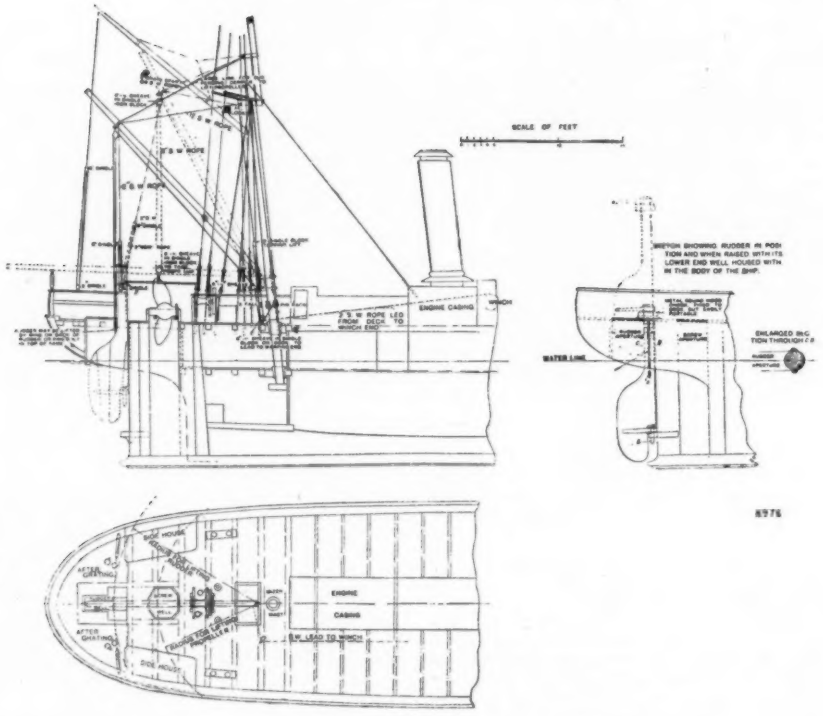


FIG 4.—METHOD OF SHIPPING AND UNSHIPPING RUDDER.

Magnetic Observatory. The fitting of a magnetic observatory was one of the special features of the design. In addition to making satisfactory arrangements for the standard compass for the proper and safe navigation of the vessel, which was in itself a difficult matter for a vessel about to penetrate such very high latitudes, it was necessary to make a special house for the purposes of a magnetic observatory, warmed by non-magnetic lamps, in which it would be possible for an observer, with a fair amount of personal comfort, to make the magnetic observations constituting such a prominent feature of the work of the expedition.

The work done in this observatory was of enormous magnitude and of great value. The observations made are being analysed and systematically dealt with by Captain Chetwynd, the present Admiralty superintendent of compasses, and will, in due course, be made public for the information of navigators and all others interested in magnetic phenomena in high southern latitudes. It may be of interest to state that the condition that there were to be no magnetic metals within a radius of 30 ft. of the magnetic observatory had very far-reaching effects. For instance, the main shrouds had to be hemp cordage, and the shrouds were set up by hemp lanyards rove through the old-fashioned wood dead-eyes.

Freeing Scuttles in Topsides. To keep the vessel as dry as possible, there was a considerable height of topsides, and, in order to prevent this height of side constituting a source of danger, there was a very liberal allowance of large free scuttles worked close down to the deck, all fitted in the manner long current in the Royal Navy, viz., so as not to open without pressure from inboard till the vessel heeled over to about 20 degrees, so as to prevent flapping and a constant ready access of water when the vessel was slightly heeled over.

Water Ballast Tank in Hold. It was recognised as a feature in the design that

the vessel might have to come back from Antarctic regions over long distances in stormy seas with little or no stores in holds, and with correspondingly diminished stability to stand up under her canvas, and, as the possibility of obtaining solid ballast could not be relied upon, it was decided to fit a water ballast tank on top of the keelson capable of holding about 60 tons of water. This was a very good arrangement, as it cost very little, added considerably to the local strength of the vessel in its neighbourhood, added also somewhat to the general structural strength, and did not diminish to any appreciable extent the coal-carrying capacity of the vessel, as on the outward voyage this ballast tank was to be filled with coal.

Galley Stoves. The sides of these were lagged with asbestos.

Skylights. These were glazed with two thicknesses of glass with a 4 inch air space intervening.

Lagging under the Deck. The under side of the upper deck over the living quarters was lagged with 1½ in. asbestos secured in place by match-boarding.

Living Spaces. Two French Salamander stoves were fitted in the men's quarters. They were of the closed-in kind with talc doors. The foremost stove in each compartment had a downcast pipe fitted to it to deliver fresh air round the body of the stove to be warmed before entry into the general space of the compartment. The afterstove in the compartment was fitted with an outside lag casing round the funnel casing proper and opening into the interior, so as to secure under average conditions a continuous up-cast of devitalised air. The exhaust round the stove funnel as a rule worked satisfactorily, but sometimes it reversed. The chief engineer officer, Mr. Skelton, expressed the opinion that the ventilation of any space in a Polar ship in winter quarters could only be made absolutely satisfactory by employing some method of forced draught fans, which, however, would mean complication of fittings and great expense. The average consumption of coal in the second year of winter quarters when everything was fully understood was as under:

Galley cooking, 9 cwt. per week; ward room, 3 cwt. per week; crew spaces, 3 cwt. per week; total, 15 cwt. per week.

Propelling Machinery and Boilers. This was designed by Engineer Commander P. Marrack, R.N., and was constructed in the main by Messrs. Gourlay Bros., Dundee. Steam was supplied by two cylindrical boilers 10 ft. 3 in. in diameter, each with two furnaces, the combined total grate area being 67 sq. ft. The maximum working pressure was 150 lbs. per sq. in. The engines were of the triple expansion type, designed to develop 450 h.p. when working at 90 revolutions per minute. The diameters of the cylinders were high pressure 14½ in., intermediate pressure 22½ in., low pressure 36 in., length of stroke 30 in. The high and intermediate pressure side valves were of the piston type, the low pressure being a flat valve. Condenser cooling surface was 560 sq. ft. The propeller was two-bladed, and had a diameter of 10 ft. 6 in. and a pitch of 12 ft. As in the case of the spare rudder, all the details were arranged on the supposition that the rudder posts might be carried away in the ice, and that the stern thrust could, therefore, not be taken up by it. This meant that the usual cheese coupling arrangement could not be used.

The arrangements adopted were such that the thrust when going astern was taken up by the thrust block inside the vessel. This plan worked exceedingly well in practice.

The Armoured Cruisers "Kasuga" and "Nisshin" of the Imperial Japanese Navy.*

By Colonel N. Soliani.

The cruisers *Kasuga* and *Nisshin* are the last of a series of sister ships (ten in number) stretching over a period of about eleven years, from 1893 to 1904. They had a prototype in the earlier Italian cruisers *Carlo Alberto* and *Vittor Pisani*, which, except that the armament was less powerful, were of practically the same design. As a main armament, the *Carlo Alberto* and *Vittor Pisani* had twelve 6 in. guns, while the *Garibaldi* (the first of the list of the *Kasuga* and *Nisshin* type) had two 10 in. guns and ten 6 in. guns. But, as a compensation, the former ships had a long forecastle, which made them more suitable to ocean steaming and long commission on distant stations.

The fact of a ship design being repeated over and over again during a long period adds perhaps to the interest it may deserve; and this may also be enhanced by the circumstance that seven out of ten ships of the list passed, before being complete, to nations other than those for which they were intended and built, including the *Kasuga* and *Nisshin*, which, commenced

* Read at the Institution of Naval Architects, April 12th, 1905.

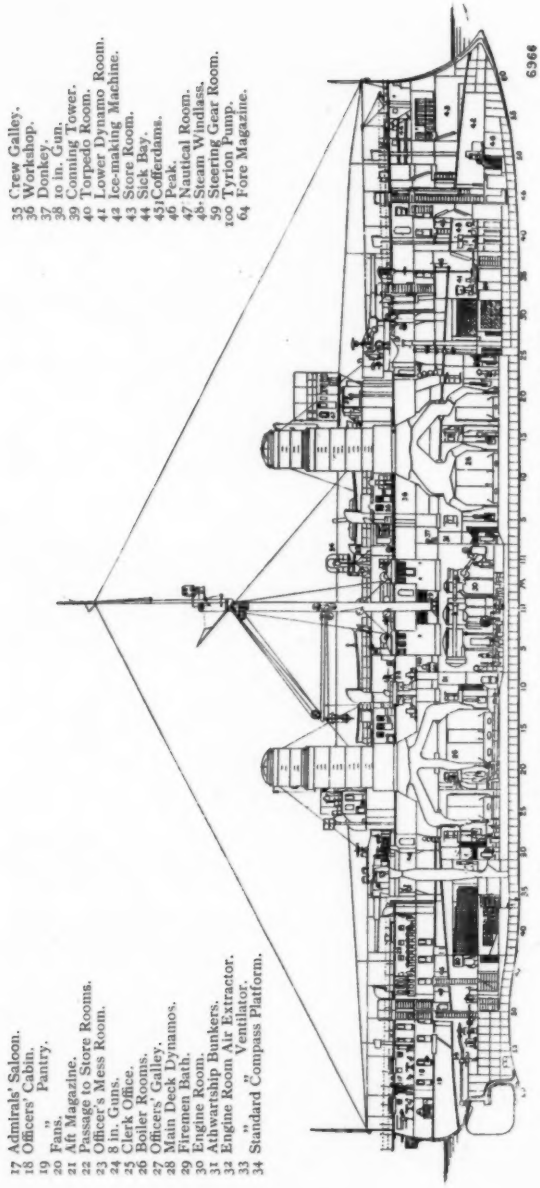


FIG. 1.—JAPANESE CRUISERS "KASUGA" AND "NISSHIN." LONGITUDINAL SECTION.

and practically completed for the Argentine Government, have taken an active and useful part in the present war in the Far East under the flag of the Japanese Navy.

The cruisers *Kasuga* and *Nisshin* were contracted for to be exactly the same as the *Giuseppe Garibaldi*, built and delivered to the Italian Government, with the exception that the boilers were to be of the ordinary cylindrical type.

The protection has lost some of its original value, although it may be said to be up to date even now. When it was planned the leading idea was to have a complete outside armour protection thoroughly efficient against shells, and an internal deck of sufficient strength to protect all the vital parts below against shell explosion, should any happen to occur inside the armoured walls. Six inches was the general thickness chosen for the side armour, and I think it may be fairly admitted that fourteen years ago, when the design of the prototype cruisers *Carl Alberto* and *Vittor Pisani* was prepared, such armour was all that could be desired. The outside protection, although not covering the ship all over, was complete in a relative sense, as the side armour not only belted the ship completely at the waterline, but, above the belt, it enclosed the whole armament and other vital parts in a central citadel which, from the belt, went right up to the upper deck, while the upper deck itself on top of the citadel and the lower deck on top of the belt were also protected so as to completely box in the defended parts. It is perhaps proper to add that the armour deck beneath the lower deck had the turtleback form then common to all protected cruisers, the deck meeting the sides of the ship underneath the lower edge of the side armour. Such an arrangement was a natural consequence of

the functions assigned to the side armour and to the armour deck itself, as above explained.

The armoured citadel, while enclosing the bases of the two turrets, afforded complete protection to the armament of 6 in. guns on the battery deck. It is well to note that the boxing of the guns inside the battery, although not carried out in such a thorough and efficient way as on the Japanese armour-clad *Mikasa*, was even then initiated, and its advantages understood, as the whole battery was subdivided into four compartments by means of a transverse bulkhead and a central longitudinal bulkhead built up in connection with the funnel casings, to localise damage, should a shell explode inside the battery.

The side armour, not being very heavy, was, for simplicity of construction, not recessed with its lower edge on a shelf, but was simply attached with its backing to the flush side of the ship. The side armour and its backing therefore projected outside the plating, thus increasing the width of the ship at the water line. A strong angle iron underneath the lower edge of the armour united it with the ship's side and gave it some support. The stepping out of the armour is a convenient point of support for shoring when docking.

The ships are three-decked: viz., in addition to the armour deck they have a lower deck, which in the central part of the ship combines with the armour deck; a main deck and a flush upper deck.

The ships may be said to be symmetrical fore and aft; the propelling engines occupy the central part, and the boilers are in two equal groups, one forward and one abaft the engines, while the armament is also equally distributed forward and aft.

The ships have one mast only, placed in the middle of the length.

The location of the propelling engines in the middle, while not free from inconvenience, as it entails a greater length and weight of shafting, and a higher position of the after boilers, which are necessarily fitted above the shaft tunnels, has some important advantages. First, it affords a real duplication of the steaming power, one group of boilers being entirely separated from the other group, with no connection whatever, so that any damage affecting one of them, whether in the boilers or in the

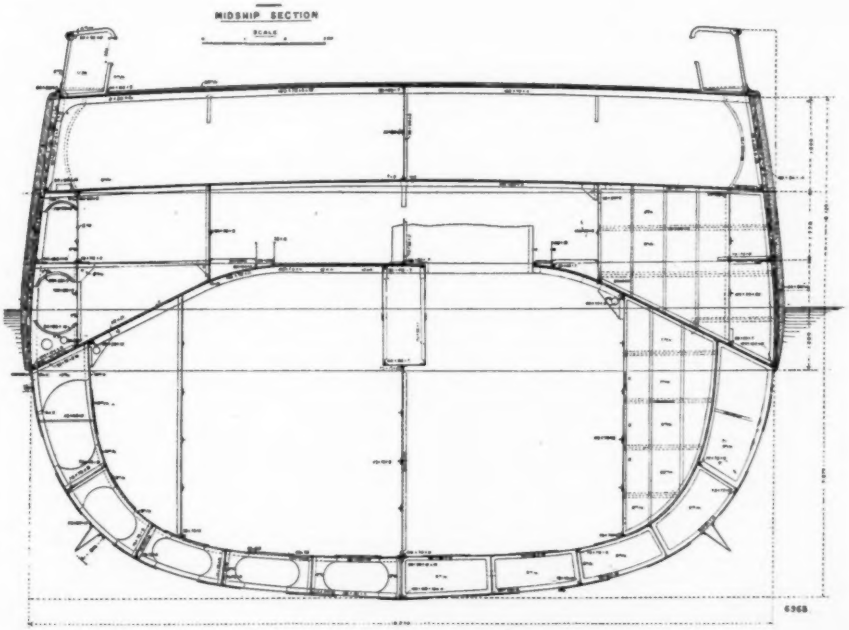


FIG. 2.—MIDSHIP SECTION.

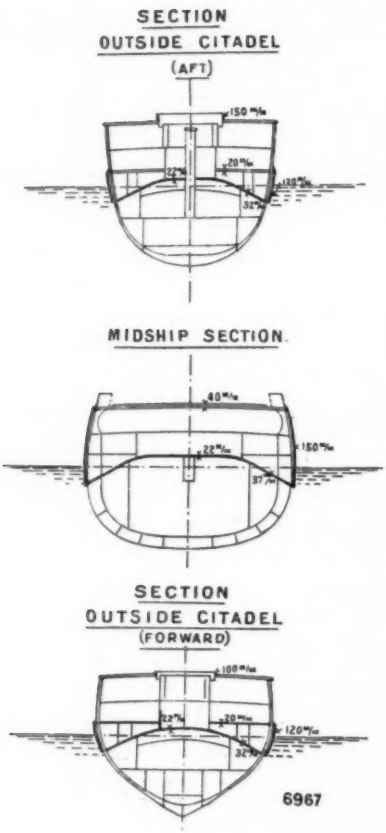


FIG. 3.

steam and feed pipes, cannot in any way affect the other group.

Greater facility of supervison and direction is obtained by the engineer in charge over the whole machinery, as without leaving the engine rooms he can keep personally in touch with and attend to either of the groups of boilers, as may be necessary. A shorter length of all pipings in connection with the engine room, and a more symmetrical and easy arrangement of the same, also result from this plan. And last, but not least, the central position of the engines is beneficial in reducing vibration in the ship due to the longitudinal couple of the inertia forces of the moving parts, which need not be so well balanced. In fact, especially on the *Kasuga* and *Nisshin*, vibrations were scarcely felt at any speed, while quite appreciable vibrations were set up by the single-cylinder dynamos forward when running alone, the ship being in harbour.

The central position of the engines, with corresponding symmetrical disposition of armament, dictated to a great extent the structural arrangement of the ships, which is, however, on the whole, the same as is usual in ships of their size and class. Attention, however, may be called to a central tunnel running along the middle line of the ship, close underneath the armour deck and between and above boilers and engines. The idea of such a tunnel was taken from English warships built or building at the time, and which had a similar central passage. But while in the British ships the side bulkheads of the tunnel went right down to the inner bottom and formed magazines below, in the Italian ships, failing the necessary space below, they were contented with the tunnel above, which, as in the English ships, was intended as a thoroughfare for easy communication between the various machinery compartments, for easy and accessible passage of electric wires, speaking tubes, telegraphs, for the manœuvring of the main drainage valves, &c., and for eventual conveyance of ammunition from end to end, should necessity occur. This last utilisation was, however, subsequently discarded, the tunnel being shut at the ends, with no communication with the ammunition compartments.

The tunnel was supported in the engine rooms by the central longitudinal bulkhead which separates the two engines, and by pillars in the boiler-rooms, in two rows along the central longitudinal passage between the boilers.

In addition to the usual cofferdams around the hatchways of the protective deck, a cofferdam about 30 in. wide was built at the side of the ship from the protective deck up to a main deck to allow leakages to be stopped at the sides, and the slopes of the armour deck to be cleared of water, should damage occur to the armour belt.

The specified speed of twenty knots was realised in nearly all the ships, including the *Kasuga* and *Nisshin*.

The coal endurance also, as reckoned by the 1,000 tons of coal (increased in the *Garibaldi* and *Kasuga* and *Nisshin* to 1,190 tons) the ships could carry, was fairly good, and quite ample for ships intended for Mediterranean service.

The keel of the *Rivadavia* (now *Kasuga*) was laid on March 10th, 1902, and the ship

was launched on October 22nd. The keel of the *Moreno* (now *Nisshin*) was laid on March 29th, and the ship was launched on February 9th, 1903.

Before the end of 1902 all the machinery for both ships was completed and ready to go on board. As previously stated, both ships were to be a repetition of the *Giuseppe Garibaldi*, built by the same firm of Messrs. Gio. Ansaldo & Co. for the Italian Government, with the exception only of the boilers, which were to be cylindrical in lieu of the Niclausse water-tube type.

The cylindrical boilers being heavier, in order to simplify matters with regard to speed, it was agreed in the contract that the specified speed of twenty knots of the *Giuseppe Garibaldi* was to be obtained under precisely the same conditions of draught as in the trials of the latter. The conditions of air pressure in the stokeholds were, of course, modified to suit the different types of boilers: $\frac{1}{2}$ inch of air pressure was allowed for natural draught and not over 1·6 inches for forced draught trials.

GENERAL DIMENSIONS AND DATA.

Length over all	111·730 metres.
,, at water line ...	108·860 ,,
,, between perpendiculars ...	104·860 ,,
Moulded breadth	18·200 ,,
Breadth outside armour ...	18·710 ,,
Moulded depth	12·190 ,,
Draught on trials { forward	6·600 ,,
Draught on trials { mean ...	7·100 ,,
Draught on trials { aft ...	7·600 ,,
Displacement on trial ...	7·400 met. tons.
Indicated horse-power ...	14,800 met. H.P.
Speed	20 knots.
Total coal capacity ...	1,190 met. tons.
Rudder area	16·98 sq. metres.

The hull is built of mild Siemens-Martin steel, no special steel being used anywhere. Wood was limited to upper-deck planking, which is of teak, and to cabins and saloon furniture. No lining was fitted in the magazines. Shelves in magazines and shell-rooms were all metallic.

The armament of the two ships is as follows:—

	Kasuga.	*Nisshin.*
10 in. guns	1	—
8 in. ,, ...	2	4
6 in. ,, on main deck ...	10	10
6 in. ,, on upper deck ...	4	4
3 in. ,, on superstructure	6	6
3 in. ,, at ends main deck	4	4
1·8 in. ,, on superstructure	6	6
Machine guns	2	2
Torpedo tubes (above water at sides)	4	4

All guns have a wide range of fire, both horizontally and vertically, as follows:—

	Horizontal Range from Athwartship.		Vertical Range.	
	Forward.	Aft.	Elevation.	Depression.
	Deg.	Deg.	Deg.	Deg.
10 in. gun	90	45	35	5
8 in. guns, forward ...	90	45	25	5
8 in. ,, aft	45	90	25	5
6 in. ,, upper deck, forward ...	90	20	20	7
6 in. ,, upper deck, aft ...	20	90	20	7
6 in. ,, main deck, forward ...	90	20	15	7
6 in. ,, main deck, centre ...	60	60	15	7
6 in. ,, main deck, aft ...	20	90	15	7

The turret guns have, as usual, a direct supply of ammunition from the ammunition-rooms below by means of a hoist independent of the revolving turret structure.

The 6 in. ammunition is raised from the magazines to the main deck by means of two continuous single chain hoists, one at each end of the main deck battery, whence the ammunition is carried on beam rails to the 6 in. guns of the battery and to the hand scuttles of the 6 in. upper deck guns. Minor ammunition is raised from magazines to the main deck and from the main deck to the upper deck by hoists of the alternative type.

The working of turrets and hoists is by electric motors and gear.

The propelling machinery consists of two twin sets of vertical triple-expansion three-cylinder engines, located side by side in the central part of the ship, in two adjacent independent compartments separated by a central longitudinal bulkhead. Steam is supplied by eight cylindrical boilers in two groups of four boilers each, one abaft and one forward of the engine-room. Each group of boilers consists of two double-ended and two single-ended boilers in two separate compartments, the double-enders being in the large compartment near the engine-room. Each group has one funnel.

Forced draught is obtained by means of twelve steam fans, two in each stokehold, under the closed ashpit system, the fans being fitted as low down as possible, to ensure good ventilation of the stokehold. Care has been taken to balance as well as

possible the reciprocating parts of the propelling engines, but no special contrivance was employed.

The dimensions and figures relating to engines and boilers are as follows:—

Sets of Engines	2
Cylinders, diameter, high pressure	1·010 metres
Cylinders, diameter, medium pressure	1·600 ,,
Cylinders, diameter, low pressure	2·360 ,,
Stroke	1·170 ,,
Power at forced draught ...	14,800 I.H.-P.
Revolutions per minute at full power	106
Speed (at forced draught) ...	20 knots
Condensers, cooling surface (total)	1,360 sq. met.
Diameter of boilers (mean)...	4·280 metres
Length of shell of four double enders	5·710 ,,
Length of shell of four single enders	2·970 ,,
Number of furnaces (total)...	36
Diameter of ,, (mean)...	1·104 metres
Working pressure	165 lbs.
Total grate surface	82·62 sq. met.
,, heating surface ...	2,262·90 ,,
Diameter of funnels (inside).	3·05 metres
Height of forward funnel above fire grates... ...	22·62 ,,
Height of aft funnel above fire grates...	21·50 ,,

The steam trials were carried out along the Eastern Riviera, near Rapallo, on the official measured base, 6,035 metres long.

Both ships went on the official trials at sea after one mooring trial and one preliminary trial at sea, and with clean bottom just out of dock. The contract conditions of trials were simply a repetition of those set out by the Royal Italian Navy for the *Giuseppe Garibaldi*, and the same results were to be obtained. The trial conditions of the *Giuseppe Garibaldi* did not contemplate speed (the ship's design being from the Italian Naval Construction Department), but only development of steam power, and were as follows:—

One natural draught trial of six hours' duration, in which the engines were to develop a mean power of 8,600 i.h.-p.

One forced draught trial of one and a half hours' duration, in which the mean power developed was to be not less than 13,500 i.h.-p.

In the natural draught trial the coal consumption per indicated horse-power per hour was not to exceed 0·900 kilogs. (about 2 lbs.).

During the natural draught trials of the *Giuseppe Garibaldi* the air pressure in the stokeholds was nil, the Niclausse water-tube type of boilers, with ample grate surface and small resistance to passage of gases, requiring no assisted draught. In the case of the Japanese cruisers, to compensate for the smaller grate area, and for the greater resistance to the passage of combustion gases through the tubes and flues, an air pressure of half an inch was admitted for the natural draught trials, as is customary in the British Navy for cylindrical boilers.

According to contract, the air pressure in stokeholds during forced draught trials was not to exceed 40 millimetres of water, as said above.

The results of the steam trials of both ships, *Kasuga* and *Nisshin*, are collected in the annexed table:—

Date of Trial.	Duration of Trial.	Draught. Forw.	Draught. Aft.	Draught. Mean.	Displacement in Metrical Tons.	Sea.	Wind.	Mean Air Pressure in Boiler-room.	Mean Steam Pressure in Boiler.	Mean Vacuum in Condensers.	Revolutions.	I.H.P. Star.	I.H.P. Port.	I.H.P. Total.	Speed in Knots.
STEAM TRIALS OF CRUISER "KASUGA."															
22 July, 1903	Hrs. 6	Met. 6·61	Met. 7·47	Met. 7·07	7,360	Calm	Light	6	165	27½"	93	5,210	4,964	10,174	18·46
29 Sept., 1903	1½	6·75	7·45	7·10	7,400	Calm	Light	29	165	26"	106	7,450	7,494	14,944	20·05
STEAM TRIALS OF CRUISER "NISSHIN."															
26 Oct., 1903	6	6·63	7·48	7·06	7,347	Calm	Light	9·5	165	28·2"	94·3	5,340	5,348	10,688	18·74
6 Nov., 1903	1½	6·76	7·47	7·11	7,413	Calm	Light	35	165	28"	106·5	7,439	7,457	14,896	20·15

The electric power station, which in the *Giuseppe Garibaldi* consisted of four continuous current dynamos, having a total power of 120 kilowatts, has been increased by 25 per cent. by the addition of one similar dynamo. The five dynamos were located, three in the dynamo-room below the armour deck, and two on main deck inside the armoured citadel. These two dynamos were intended for general use, and also as a reserve for the main station.

The dynamos of the continuous current, four poles, shunt-type, were made by the Ansaldo firm, and worked at 110 volts and 300 ampères. The steam engines, of the compound tandem type, were supplied by Messrs. F. Tosi & Co., of Legnano.

The power plant, in addition to supplying current for the electric lighting of the ship, consisting of nearly 500 lamps, and five searchlights—four of 24 in. and one of 30 in.—also supplies current to many electric motors, viz., main artillery motors, ammunition elevators, ventilating fans, ash elevators, refrigerating machine, workshop, &c.

All the wires, the principal of which are solid bars, are enclosed in metallic watertight casings, or protected by Bergman's tubes.

The watertight doors for communication between the machinery compartments are all high up in the central tunnel, and are of the sluice type, with rack and pinion. No other communication is needed. However, for convenience in ordinary service, two more watertight doors were fitted below in the main bulkheads separating the single from the double-ended boiler compartments, and in way of the central passage between boilers. These two doors are of the hinged rack-and-pinion type invented by Major Quarleri, Naval Architect in the Royal Italian Navy, which, by the single working of the pinion shaft, are not only swung round, but locked and unlocked also.

All other important doors in the hold are of the slide rack and pinion type. On the decks above, all doors are hinged.

The general ventilation of the ship is secured by numerous electric fans, and is on the vertical independent system, each compartment having an inlet and exhaust of its own, so that there is no need of impairing the efficiency of watertight bulkheads by ventilating pipes passing through them. Moreover, inlet and exhaust having straighter leads, the efficiency of ventilation is better secured.

On Elastic Limit.*

C. Bach, in a previous paper published last year, pointed out the fact, borne out by his experiments, of the existence of an upper and a lower elastic limit in any material showing the phenomenon of yielding. The "upper elastic limit" is the tension σ_o where the yielding begins, while the smallest tension σ_u to which the load during the yielding falls is what the author understands by "lower elastic limit." In the present paper, the author records some recent results obtained in the course of further experiments on the same problem.

In connection with tests on a sheet about 20 mm. in thickness from a steam boiler that had been in operation for eight years, the following facts were stated:—(1) There is a great difference in the values of the elastic limit as obtained, on one hand for a flat rod, and on the other for round rods made from the same sheet. (2) There is a great difference also in the tensile strengths of the flat and round rods respectively. A further investigation on seven boiler sheets of tensile strengths, varying between 3,400 kgs. per sq. cm. and 5,000 kgs. per sq. cm., brought out the following facts:—(1) The round rods mostly gave far higher figures of σ_o than flat rods, while the values of σ_u show less marked departures. The difference between the two values is considerably greater with round rods than with flat rods.

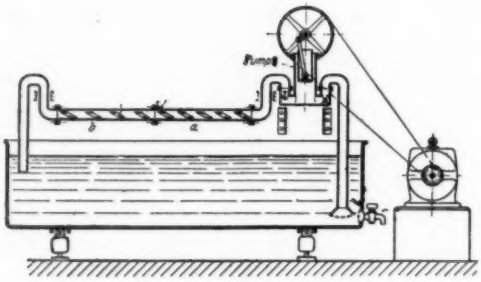
These results, as well as those derived from subsequent experiments, can be accounted for by the following:—

(1) The flat rods retain the rolling skin, while the round rods contain material exclusively from the inner parts of the sheets. (2) The form of the cross section of the rods has an influence on the results, the transverse contraction of the various fibres of the rod being hampered to a degree depending on this form. The same dependence, though to a smaller degree, is, by the way, observed also in the case of the tensile strength.

The Protection of Copper against Corrosive Action of Sea Water.

Copper and copper alloys have long been used as a specially valuable constructive material in ship building, and as far back as in 1761 the British Navy commenced fitting her ships with copper plates to protect them against incrustation by shells.

* *Zeitschrift des Vereines Deutscher Ingenieure*, No. 15.



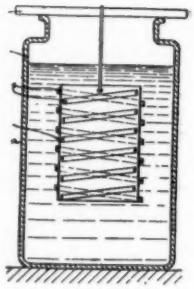


FIG. 1. FIG. 2.

PROTECTION OF COPPER.

The physical properties of copper and bronze allowed of many parts of the ship and machinery being given a light and durable design, and this applies especially to any kind of piping. As the speeds of ships were increased, the weight had to be reduced everywhere, and even such objects as had formerly been made nearly exclusively from cast iron were now manufactured from copper or copper alloys. The destructive action exerted by sea water on many copper parts in contact with water was noted about this time, and the phenomenon investigated.

M. Uthemann, in a recent contribution to the *Zeitschrift des Vereines Deutscher Ingenieure* (No. 18), records a series of experiments made at the imperial shipyards of Danzig, and which were carried out both with flowing and still water. The apparatus used in connection with the former is shown in Fig. 1. The lengths of pipe, *a*, *b*, are inserted in a conduit through which sea water is pumped from a large reservoir. The pump is operated by an electro-motor, working for ten hours each day, the water being otherwise at rest in the conduit and reservoir. The conditions are made as similar as possible to those obtaining on board. The pumps are of bronze. Both tubes protected by iron and non-protected tubes of the same material were tested.

The experiments in still water (Fig. 2) were made on thin-walled cylinders suspended in glass containing vessels. The cylinders consisted of copper obtained by metallurgical processes, and were protected by iron, either internally only, or both internally and externally.

These experiments extended over a period of two years, and the tables given by the author show that a protected iron cover will result in an increase in the weight, not only in the case of the copper, but of copper alloys, while without such a protection both copper and its alloys, even those called "seawater-proof," will undergo a continual decrease in weight. The use of iron covers should therefore be emphatically recommended.

A Fireproof Theatre of Armoured Concrete.

THE firm of G. A. Wayss & Co. are building a miniature fireproof theatre of armoured concrete, which is specially intended for fire tests. It is to serve as a model structure where any safety devices which have so far been suggested against the danger of fire, as well as any that may be proposed in future, will be tested.

The theatre is to be fitted with a stage 7·5 mm. breadth and 6 mm. depth, separated by an iron curtain from an amphitheatre 5·5 mm. in breadth and 7 mm. in depth. The stage consists of stationary and rolling floors, a working gallery to the right and another to the left, and an adjusting bridge. The latter parts are of iron, and are suspended by ties of the same material from the ceiling, which consists of massive Monier concrete. The amphitheatre consists of a simple gallery with lateral staircases leading into the open. Special rain attachments are to be provided.

In connection with the experiments contemplated, the outlets through which the smoke gases generated by a fire may escape will be studied with special care. Any decorations exposed to combustion will be fitted as in actual operation. It is thought possible by these experiments that devices may be discovered for protecting the

amphitheatre from a stage fire. If the fire gases are led away promptly and safely from the stage into the open air, and if sprinkling proves an efficient fire extinguishing agent, an amphitheatre of fireproof construction might be safe against any danger of fire. According to a report in *Beton und Eisen*, it is contemplated carrying out fire tests in the presence of filled amphitheatres.

Utilising Nitrogen from the Air.

Dr. K. Arndt, writing in No. 16 of *Dingler's Polytechnisches Journal*, discusses the process designed by Professor Frank according to which nitrogen is led over heated calcium carbide, thus obtaining a compound of calcium, carbon and nitrogen (calcium cyanamide), called by the inventor "lime nitrogen." The raw product, which contains from 20 to 21 per cent. of nitrogen, can be used immediately as manure. Eight to fourteen days before the sowing, 150 to 300 kgs. (according to the condition of the ground) of lime nitrogen are spread out on each hectare of ground, this being mixed with about the double quantity of dry soil, and ploughed immediately to a depth of from three to five inches. A large factory is to be taken into operation in Italy in the course of this year, where 3,000 H.P. is to be employed for the production of lime nitrogen. According to Frank's data one electrical H.P. per hour will give, during a year, 1,250 kgs. of lime nitrogen. The product should be protected against moisture, lest some nitrogen be lost in the form of ammonia.

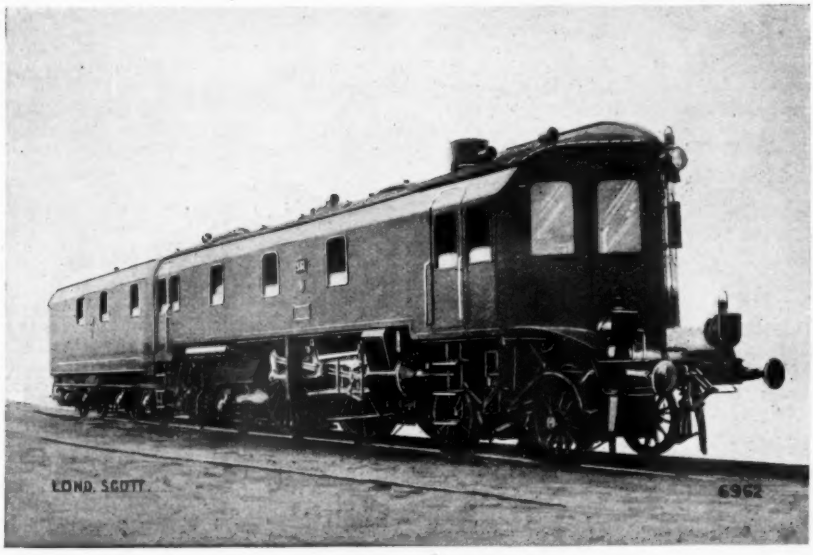
Whereas this process requires an enormous quantity of electricity, Nature herself dispenses with the use of any apparatus. In fact, the bacteria dwelling in the root nodules of leguminosa work the nitrogen of air, preparing from it food for their hosts. Hiltner, of Munich, has succeeded in obtaining from these nodules considerable amounts of a substance by means of which he expects to find a biological process able to compete with the above chemical method for the utilisation of atmospheric nitrogen.

RAILWAY NOTES.

The High-Speed Locomotive, Prussian State Railway Department.

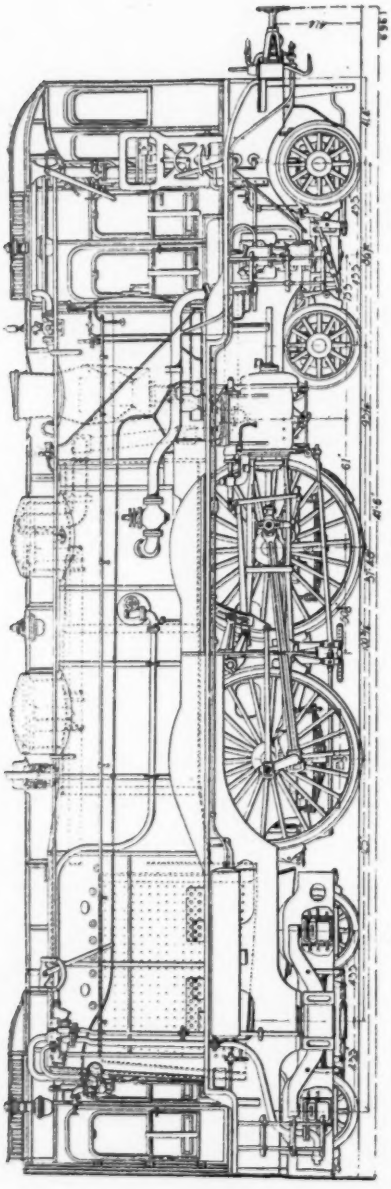
Spurred on by the recent successes of the high-speed electric tests conducted on the 14½ miles stretch of trial railway situated between Marienfelde (Berlin) and Zossen—running in the direction of Dresden—German locomotive engineers have been actively engaged in endeavouring to increase the speed and capacity of the steam locomotive, in keeping with the demands of traffic increasing from year to year, and to thus create a locomotive which may enter on the contest with the electric motor with prospects of ultimate and complete success. For suitable employment of high-speed locomotives, those stretches of line must, of course, be selected which connect great traffic centres with each other, and pass exclusively, or mainly, through level country, thus offering no difficulty with respect to gradients or curvature. In the accompanying photograph is illustrated a locomotive which is novel in its appearance and general design, and one which, after having been exhibited last year at St. Louis Exposition, is to be very shortly introduced for working express passenger services on the Prussian State Railways. The locomotive—which, before being shipped to the United States, maintained, in the course of some official trials, a speed of 82 miles an hour with a six-car train, representing a tonnage of 240; a speed of 87 miles an hour, with five cars, 200 tons; and a speed of 92 miles with three cars, 120 tons—was built by the well-known engineering firm of Messrs. Henschel & Son, of Cassel, Germany, and has recently been purchased by the Prussian State, preparatory to its being introduced for the fastest express services on the section of railway—177 miles in length—which separates Hamburg and Berlin. This stretch of line complies in a high degree with the requirements stated in a previous paragraph, as—at the last census—Berlin had a population of 1,888,000 inhabitants, and Hamburg one of 706,000 inhabitants, whilst the intervening country is flat and sandy, with no considerable town in it. At present the service is one of ten trains

in each direction daily, the fastest covering the distance in 3 hours 27 minutes, whilst there are four trains which accomplish the journey to Hamburg in less than 4 hours. The number of through passengers between these two commercial centres averages about 1,150 daily, a considerable increase having taken place during the past ten years. In designing high-speed locomotives, two factors are specially to be considered:—(1) the resistance of the air; and (2) the disturbing movements due to the motion backward and forward of the massive driving parts of the engine. The results derived from the trials on the Berlin-Zossen section were made the basis for ascertaining the resistance of the air, as these alone—among the large number of formulæ drawn up for high speeds in different countries on the basis of trials—gave reliable results. In order to reduce the resistance of the air to a minimum a complete departure was made from the design hitherto adopted. The locomotive, along its entire length, including the tender, was "housed" in sheet metal, offering the least possible points of attack to the air in its passage. To diminish yet further the resistance of the air, the front of the locomotive narrows down and converges. Only few parts of the locomotive protrude from the metal casing, such as the upper part of the chimney stack, the arch of the two domes, and the ventilation superstructures, together with the lanterns. This housing, nevertheless, requires the driver's cab to be separated from the stoker's, the former being brought in front of the smoke-box on the head side of the locomotive, so as to give the driver a free view of the road. Much greater difficulties were met in obviating the effect of the motion to and fro of the driving masses, which might give rise to disturbing oscillations of the locomotive, which, at high speeds, would become positively dangerous. The movement of irregular oscillation around the vertical axis of gravity is the most dangerous. The practice almost invariably adopted has been to adjust the outside driving cranks at 90 degrees on each side, but this results in a motion being imparted to the engine, tending to make it revolve in a horizontal plane. This motion is caused by the acceleration and retardation of the uncompensated masses moving to and fro. This irregular oscillating motion increases as the square of the speed, and, under unfavourable circumstances, may attain dangerous proportions, and, in some instances, lead to the derailment of the engine. This irregular oscillation is limited by the construction of four-cylinder engines, but is completely remedied by three-cylinder engines (Wittfield system) alone, and this, for the reason just stated, is the type which has been adopted for the twelve-wheeled four-coupled high-speed locomotive, illustrated herewith. In this locomotive, the cranks of both outside cylinders have a parallel direction, whilst those of the inside cylinder—which drives the middle of the axle—is horizontally inclined to both the others at 90 degrees. Another disturbing motion must be taken into consideration, and one which is felt parallel to the length of the locomotive, and is due to its increasing pitching. This, in view of the great weight, need not, however, be very seriously taken into account, and this derangement must be regarded as the "lesser evil" for high speeds. The locomotive is supported on six axles, of which the two middle axles are constructed as driving axles of 86⅝ in. diameter, coupled with each other, whilst the four running axles are joined in pairs in a front and rear bogie, the pivots undergoing lateral shift in order to maintain mobility when negotiating curves. The boiler is of unusually large dimensions, possessing heating surface of 2,776 sq. ft., the grate area being 45·4 sq. ft. In order to attain the last-named dimension, the fire-box has been expanded below—two fire doors adjoining each other in the back plate of the fire-box, so as allow of the grate being properly fed. For the purpose of covering the 345 boiler tubes, which are 1¾ in. internal diameter, while reducing the diameter of the barrel to the lowest minimum the fire-box has been made wider, and its connection with the barrel is effected by means of a conical piece, thus obviating the necessity for longitudinal staying. The staying of the fire-box is effected in the usual way by bolts and roof, cross and bottom stays. The barrel, consisting of one conical and two cylindrical plates with an average diameter of 5 ft. 3¾ in., carries two steam domes, one on the first and the other on the second plate, in order to increase the steam space. A steam collecting tube, suspended in the upper part along the longitudinal axis of the boiler, conducts the steam into the rear dome, whence it reaches the front dome by a connecting tube and the steam admission tube through the starting lever. By this means water carried with the steam is, for the most part, separated, and the steam reaches the cylinders in as dry a condition as is possible. A double Ramsbottom safety valve, arranged on the second plate, allows the excess steam to escape. The stable



HIGH-SPEED LOCOMOTIVE, PRUSSIAN STATE RAILWAYS.

connection of the boiler with the frame is effected by means of one front and two lateral smoke-box bearers—the movable connection being effected by means of a circular boiler bearer, four lateral fire-box bearers, and a shifting piece screwed on to the back plate of the fire-box. The frame, in contrast to the design hitherto used on the Prussian railways, is made up of two parts, the frame plates of which are at different vertical levels. The front part, which receives the cylinders and is supported on the front bogie truck and the two driving axles, lies within the axles, so as to prevent protrusion of the outside cylinders of 20⅝ in. diameter, beyond the outline as prescribed. The two frame plates are held together by the buffer beams, the cylinder stays and the other horizontal and vertical stays. The rear frame section has a greater internal width between the two frame plates, in order to allow of taking the large fire-box between them, as otherwise it would have been impossible to avoid placing the boiler very high and the fire-box on the frame, which latter was not practicable, on account of the great height of the fire-box, as this would have exceeded the prescribed dimensions and, in addition, afforded a largely increased surface to the friction of the air. The back end of the frame is supported on the second bogie truck, and is connected with the front part of the frame by a powerful vertical cross-stay lying in front of the fire-box, and by the projecting frame ends lying against the slide bar holders. The unusual length of locomotive and tender required that they should be capable of being easily separated, to permit of their being turned separately on the turntables, and for this purpose they are connected by draw-hooks and a coupling loop, drawn together by a lever brake, operated from the stoker's cab. Steam is first conducted to the high pressure cylinder, constructed between the frames, and passes from the latter through the receiver to the two low pressure cylinders lying outside. The diameter of all three cylinders is 20⅝ in., the proportion of capacity of the two low pressure cylinders to the high pressure cylinder being as 2 is to 1. The steam distribution is effected by means of equilibrium valves, operated by three separate distributing motions on the Heusinger von Waldegg system. A reversing gear on the Kuhn system gives the low pressure cylinders a uniform filling of 70 per cent., whilst the high pressure cylinder can be adjusted at a degree of filling between 20 and 78 per cent.,



DETAILS OF HIGH-SPEED LOCOMOTIVE.

by means of a distributor fitted in the driver's cab. When the high pressure cylinder is filled to the extent of 30 to 40 per cent., and the low pressure cylinder to that of 70 per cent., the working proportion of both cylinders is approximately equal. This degree of admission also corresponds to the nominal capacity of the locomotive of 1,300 h.p. which is required to move a train of 310 tons weight (including locomotive and tender) at a speed of 81 miles per hour. The piston motion of the high pressure cylinder is transmitted to the crank axle of the front set of driving wheels, whilst the pistons of the two low pressure cylinders work on the rear driving axle. The low pressure cranks are at an angle of 90 degrees to the knee crank, so that the low pressure cranks follow on after the high pressure crank. For the angle between the coupling rod cranks, at 90 degrees to each other, and the driving rod cranks of the low pressure cylinders, 45 degrees were determined on, with a view of transmitting the greatest possible amount of the power from the driving axle through the coupling rod to the coupling axle, and driving round at a dead point of one of the two driving rod axles, and further to the most favourable possible action on the outside crank pin, which in this locomotive has been constructed as a counter crank. All parts, such as the crank axles, the high pressure connecting rod, the coupling rods and the counter crank pins, are composed of 5 per cent. nickel steel. In order to render starting possible at the dead point of the high pressure crank, an automatic, or hand-worked, starting valve is inserted between the steam exhaust ot the high pressure cylinder and the receiver. Each time, before starting, the valve is closed so that the high pressure cylinder is shut off from the receiver, and, at the same time, fresh steam of low tension is conducted into the low pressure cylinder by a small piston slide. If the high pressure crank is really at the dead point, the low pressure cylinders first of all alone exert a pull under fresh steam until the high pressure cylinder likewise obtains steam and the steam expelled from it automatically opens the valve by its surplus pressure. By this means the fresh steam admission to the low pressure cylinders is likewise cut off and the compound action restored. The starting lever is operated from the front cab. A suitable device is provided in order to allow of closing off the starting lever, in case of danger, from the stoker's cab, but it cannot be opened from this point. All the fittings required for both the driver and the stoker are provided in duplicate. In the

rounded front wall of the housing, doors with fixed windows are provided on both sides to allow of easy access to the smoke-box and boiler tubes, whilst next to these—to the right and to the left—are placed large double windows. To light the side passages and to ventilate the interior thoroughly, the windows in the side walls can be lowered, whilst, in addition, there is a ventilating super-structure with adjustable shutters above the driver's and above the stoker's cab, affording very efficient ventilation. The driver's or the stoker's cab is mounted from each side of the locomotive through two entrances, which can be closed off by doors with movable windows. The passage to the tender, which is "housed" in the same way as is the locomotive, is rendered possible through a broad rubber band, at the rear end of the locomotive housing, and beneath which the tender "house" protrudes. The tender is fitted with two double axle bogie trucks, and has a capacity for 4,400 gallons of water and seven tons of coal. The filling of the tank is effected by a funnel inserted on one side, whilst the coaling is performed through two chutes in the roof. The passages on both sides of the cisterns are lighted by movable windows in the same way as is the locomotive, whilst, in order to protect the stoker's cab from grit and dust when coaling, the coaling space can be closed off by a rolling wall. The passage from the tender to the first carriage is effected by means of a telescopic arrangement of the same design as that used on all the principal German corridor trains. Both locomotive and tender are equipped with complete Westinghouse high pressure rapid brakes. The brake action on the four driving wheels, on the wheels of the back bogie truck, and of the tender takes place on both sides, whilst the front bogie truck—on which falls the task of guiding—is subjected to brake action on one side only. The high pressure brake is for the purpose of lessening the brake pressure after high initial pressure as the speed diminishes. Assuming an average brake pressure of 5·5 atmospheres in the cylinders, corresponding to the conduit pressure of seven atmospheres, the pressure on the running wheels of the front bogie truck is 75 per cent. on the driving wheels, the wheels of the rear bogie truck and of the tender 100 per cent. of the rail pressure, the weight of the tender (half loaded with water and coal) being here taken into account. In order to facilitate the placing of the engine in front of the train, there is fitted at the rear end of the tender a brake valve which is operated by one of the two stokers, and communication with the driver is effected by means of a steam whistle and speaking tube. The locomotive and tender are illuminated inside by gas lanterns, placed in the ventilation superstructures, in the end of the tender and in the passages. There is a complete air sanding apparatus of the Bruggemann system—a steam-heating and tyre-wetting device—an appliance for blowing out the boiler tubes by means of compressed air, and two-speed gauges on the Frahm and Haushalter system. The following are the leading dimensions:—Gauge, 4 ft. $8\frac{1}{2}$ in.; diameter of cylinders, $20\frac{3}{8}$ in.; piston stroke, $24\frac{7}{8}$ in.; diameter of driving wheels, 7 ft. $2\frac{5}{8}$ in.; diameter of bogie wheels, 3 ft. $3\frac{3}{8}$ in.; rigid wheel base, 8 ft. $4\frac{3}{4}$ in.; working pressure, 200 lbs. per sq. in.; grate area, 45·4 sq. ft.; heating surface, 2,776 sq. ft.; water capacity of tender, 4,400 gallons and space for seven tons of coal. The weight of the engine (empty) is $75\frac{1}{2}$ tons and that of the tender 31 tons, but this weight, in running order, is increased to 85 tons for the locomotive, and 58 tons for the tender, the adhesive weight of the locomotive being 32 tons, while the remainder is distributed on the front and rear bogie trucks bearing $24\frac{1}{2}$ tons and $28\frac{1}{2}$ tons respectively.

Oscillations of Railway Vehicles on Suspended Springs.*

An investigation of the oscillations of railway vehicles offers great interest, both on account of the derailments any excessive oscillations may give rise to, and because of the disagreeable effects of such shocks on railway passengers, the rolling stock and the track. In view of the increasing speeds of rapid trains, this item should receive more and more attention. Such oscillations are due either to a defective state of the rolling stock or to defects in the track.

Many engineers have dealt with the problem at issue, and have first examined such oscillations as are due to the stock, while those produced by the track itself have been studied more particularly of late years. The most important factor in this connection is the periodical vertical differences of level occurring at each rail joint, and as the joints of the two rails are generally situated in front of each other, their respective effects are exerted on the two wheels of the same axle at the same

* By G. Marié (Comptes Rendus de l'Académie des Sciences).

time, giving rise to simultaneous vertical oscillations, unless horizontal oscillations complicate the phenomena. The opinion has been enunciated that these vertical oscillations would prove particularly dangerous if there exist synchronism between the time employed by a vehicle in traversing the length of the rail and the duration of its natural oscillations on its springs, and this special speed is what has been called "*critical speed*."

The author states that railway vehicles cannot possibly be prevented from running sometimes at their critical speed, this corresponding frequently to the most usual speeds. Such divergent oscillations as should result according to theory, however, fail to be produced generally, owing to the friction of the spring plates, guides, etc., which factors had not been taken into account. As, however, such oscillations are liable to occur in certain cases, when they may be productive of real danger, they obviously deserve special attention. M. Marié has investigated them by means of graphic methods in a simple theoretical case and has established the following formula giving the condition of convergence:

$$h = 2 f a,$$

where h is the maximum periodical level difference of the track (about ·004 m.), f the relative friction of the spring, viz., the constant ratio between the sum of the friction of the spring, plates, guides, etc., to the corresponding value of the power of the spring, and a the pitch of the spring under fixed load (·03 m. to ·25 m. as the case may be).

This formula can be applied to almost any practical case met with in railway operation, and the following conditions are inferred from it:—

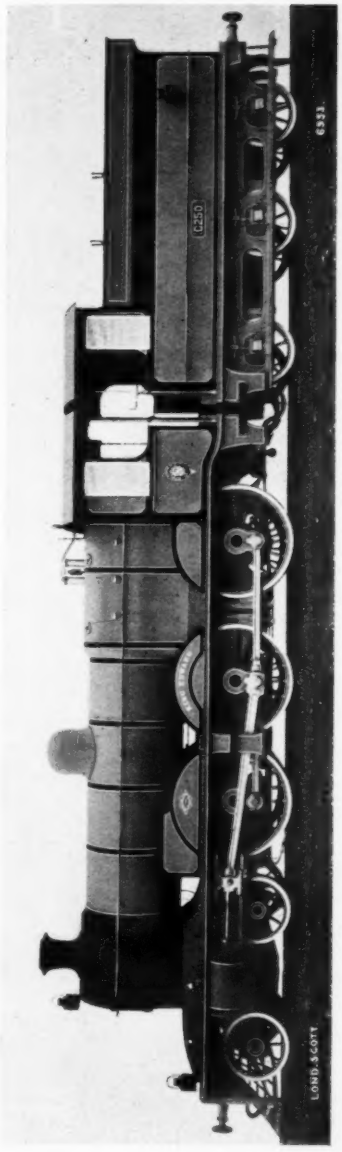
1. In order to reduce the value of h, a track as rigid as possible should be employed; 2. springs of great flexibility and at the same time a fairly high relative friction should be made use of.

If the above conditions be complied with, the vehicle will not, independently of the speed, show any vertical divergent oscillations.

Six-wheeled, Coupled, Bogie Express Locomotives for India.

In the accompanying photograph we are enabled to illustrate one of ten large and powerful six-wheeled, coupled, outside cylinder, bogie express locomotives which have quite recently been built by Messrs. Robert Stephenson & Co., Limited, of Darlington, for working the heavy mail expresses of the Bengal-Nagpur Railway Company, as between Calcutta and Bombay. These locomotives, which have been designed by, and constructed under the supervision of, Sir John Wolfe Barry, K.C.B., the consulting engineer of the Bengal-Nagpur Railway Company, are fitted with cylinders (20 in. diameter, and 26 in. stroke), having ordinary sliding valves, whilst the motion is of the Stephenson link with its excentrics on the driving axle, the rods being bent clear of the leading axle. Reversing is effected by steam and water cataract cylinder actuated by a miniature reversing lever and notched sector plate in the cab, and so arranged that by means of an ingenious automatic cut-off the reversing shaft is held in a position corresponding to the notch at which the small hand lever is placed by the enginemen. The boiler, which is of large capacity, and with its centre line "pitched" 8 ft. 6 in. above rail level, is constructed of steel plates, with copper fireboxes stayed with copper stays, the tubes being of brass. The boiler barrel has a mean diameter of 4 ft. $9\frac{9}{16}$ in., and a length of 14 ft. $1\frac{1}{2}$ in., the plates being $\frac{9}{16}$ of an in. in thickness. The fire-box, which is of the Belpaire pattern, has a length, outside shell, of 8 ft. 8 in., and a width, at the bottom, outside, of 4 ft. $7\frac{8}{8}$ in. The tubes number 196, and are of $2\frac{1}{4}$ in. diameter. The total heating surface is 1,831 sq. ft., to which the tubes contribute 1,673·5 sq. ft. and the fire-box the remaining 157·5 sq. ft. The fire-grate area is 32·184 sq. ft., and, taking 90 per cent. of the boiler pressure, the tractive force amounts to 22,922 lbs. The six-coupled wheels have each a diameter of 6 ft. $1\frac{1}{2}$ in., the bogie wheels a diameter of 3 ft. 6 in., whilst the six wheels of the tender are each 3 ft. 8 in. in diameter. The cab has been specially designed for Indian climatic conditions, affording ample protection from the power of the sun, and in place of the side windows sometimes seen on European, nearly always on American, locomotives, lowered shutters, sliding between light-angle iron framing, are provided both on engine and tender. The engine, in working order, weighs 63 tons 5 cwts., distributed thus: Bogie wheels, 16 tons 2 cwts.; leading wheels, 15 tons 14 cwts.; Driving wheels, 15 tons 15 cwts.; and trailing wheels, 15 tons 14 cwts. The tender, which has a capacity of 3,500 gallons of water and 7 tons of coal, weighs an

additional 41 tons 4 cwts., distributed thus: Leading wheels, 13 tons 9 cwts.; Intermediate, 13 tons 10 cwts.; and trailing wheels, 14 tons 5 cwts. The engine and tender, in running order, therefore, has a weight of 104 tons 9 cwts.



4—6—0 EXPRESS LOCOMOTIVE FOR INDIA.

A New Type of "High-Capacity" Mineral Wagon.

In the accompanying photograph is illustrated one of a number of 30-ton part-end-emptying bogie hopper coal wagons which are now being introduced for operation on the Caledonian Railway. These wagons, which have been built by the Leeds Forge Company for the Scottish Co-operative Wholesale Society, Ltd., of Glasgow, are 38 ft. in length over the buffers, 8 ft. 6 in. in width over all, and 8 ft. 5 in. in height from rail level, the centres of bogies being 22 ft. 6 in. apart. The wagons are of somewhat unique construction, inasmuch as they are provided with one set of centre hopper openings with the doors arranged on the Leeds Forge Company's patent system—such as is adopted in the "all-steel" wagons recently introduced for coal traffic on the North Eastern Railway—with the exception, however, that the latter have two sets of hopper openings near the centre, whilst the rolling stock illustrated herewith has, in addition, been equipped with a hopper opening at each end of the wagon. This arrangement enables the wagons to be reduced in over-all dimensions as compared with a wagon emptying at the centre only, without decreasing the carrying capacity, as a wastage of space at the ends of the wagon is obviated, owing to the slope of the end hopper. The operating gear for opening and closing these end doors has been designed on the same principle as that for the centre doors, except that one arm only of the toggle joint is connected to the door and the other arm to a fixed bracket on the headstock of the wagon, instead of each arm being connected to one of the doors Wagons emptying at the centres only, and constructed with the same height and width as the 30-ton wagons illustrated above, would require to be at least 2 ft. 6 in. longer in order to give the same capacity, or, in other words, an economy of about 7 per cent. is obtained in the length of wagon by the utilisation of the part-end emptying principle. By a special arrangement of

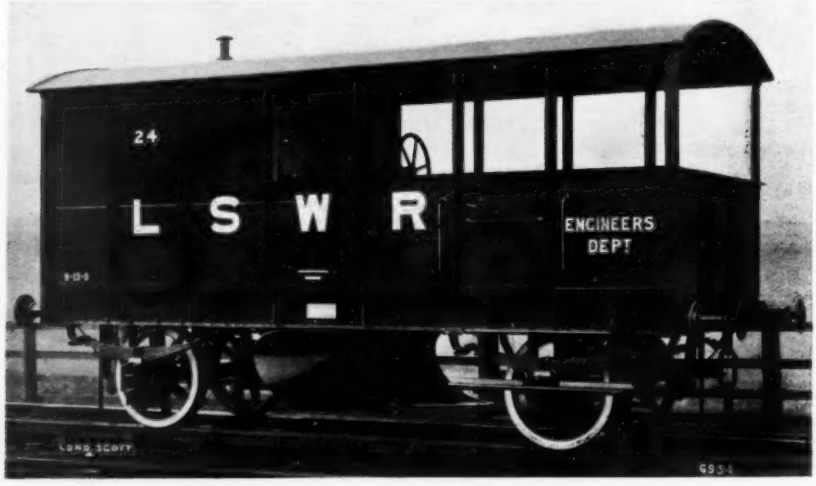
HIGH-CAPACITY WAGON, CALEDONIAN RAILWAY.

inside stanchions these wagons have an inside width of 8 ft. 4 in., whilst the over-all width is 8 ft. 6 in. only, and thus a further economy of 3 per cent. is obtained as compared with a wagon constructed with the stanchions outside, as is usual. The bogie frames and cross members of these 30-ton wagons are constructed of pressed steel frame plates, and the bogies, which are of the open-ended type, are of a simple but exceptionally serviceable design.

Ballast Ploughs and Hopper Wagons for L. & S. W. Railway.

THERE have recently been placed in service on the London and South Western Railway a number of brake vans fitted with ballast ploughs, one of which forms the subject of the accompanying illustration.

They were constructed by Messrs. Hurst, Nelson & Co., Limited, of Motherwell, to



BALLAST-PLOUGH VEHICLE, L. & S. W. RAILWAY.

NEW TYPE OF BALLAST WAGON, L. & S. W. RAILWAY.

whom we are indebted for the undermentioned information.

The brake vans with ballast plough measure 25 ft. over headstocks, and are 8 ft. 4 in. wide over the plough. The underframe is constructed of rolled steel bars, securely fastened with gusset plates and knees. The body is framed in steel with wood sheeting, and is divided into two compartments, one closed and provided with a stove, the other being open. The roof extends over both compartments. The plough is arranged with raising and lowering mechanism, and is carried by a heavy forged pin and two brackets. The main hoisting gear of the plough consists of a pair of bevel gear wheels actuated by a screw. Supplementary hoisting gear is also provided, consisting of a handle and screw. To fix the plough in either the raised or lowered position, two locking brackets are provided.

The van is provided with a screw brake, having eight brake blocks, all the gearing for which, together with that for the plough, being in the open compartment. A locker for tools, &c., is provided and arranged to act as seat.

Messrs. Hurst, Nelson & Co. have also recently delivered to the L. & S. W. Co. a number of 12-ton steel hopper wagons, one of which is illustrated in Fig. 2. The inside dimensions of these wagons are 16 ft. long by 7ft. 6 in. wide. The underframe is constructed of rolled steel bars, securely fastened with gusset plates and knees. The body plates, which are $\frac{3}{16}$ in. thick, are secured to a steel rolled bar framing. One bottom door is provided, arranged to open to one side. A controlling handle and guide bars are fitted, as are also a pin and chain to fasten the handle in various positions.

ELECTRICAL NOTES.

By Andrew Stewart, A.M.I.E.E.

An Electrically Equipped Cargo Boat.*

The high efficiency and light weight of the Diesel oil engine, together with the flexibility of electric driving, led Messrs. Nobel Bros, of St. Petersburg, to equip their oil-tank steamer *Vandal*, a vessel 245 ft. in length by 32 ft. beam and 1,100 tons displacement, with Diesel engines driving direct-current dynamos. These are situated amidships, the energy being transmitted to a motor room aft, where three electric motors, direct-connected to three propellers through short shafts, are fixed. The vessel is, as will be seen from Fig. 1, a flat-bottomed craft, with a maximum draught of 6 ft. loaded, and is used for inland navigation only, chiefly on the Volga, carrying oil from Rebinsk to St. Petersburg, a journey of about 700 miles each way. Each of the three Diesel engines, which are of the three-cylinder single-acting type, give 120 B.H.P., and are direct-connected by flexible leather couplings to three direct-current generators; each generator has an exciter mounted on an extension of the shaft, this exciter not only excites the main generator winding but the motor fields, and operates the electric steering gear, pumps, capstans, and electric lighting. The motors in the stern are controlled directly from the bridge, no engine-room telegraph being employed. The control circuits are shown diagrammatically (Fig. 2); only the small exciting current of the main generators are dealt with. The arrangement will be clear from the diagram, which shows full field on the generators, and the motors at full speed ahead, with the regulator arms (on the bridge) in the positions shown at A_1 and A. By moving the contact arms towards B_1 and B, the exciting current and, therefore, the voltage of the generators will drop, and the speed of the propeller motors will fall in proportion. When the two arms are exactly in the middle the generator voltage is zero, and the propeller motor stops; when each arm passes the centre position the propeller motor starts up in the reverse direction; when C_1 and C have been reached the propeller motor is at full speed astern. This method of controlling the propeller motors by manipulating the field current of the generators enables all the control to be effected by variations in a very small current instead of several hundred amperes, which would be the case if the main motor current were dealt with. But a still more important advantage is the absence of the time lag between the time the messages are received in the engine room and the actual change in the vessel's speed: it will be seen that the officer on the bridge controls the propeller motors directly, and a change from full speed ahead to full astern is effected in twelve seconds. The motor speed is controlled between 30 and 300 revolutions per minute; the latter corresponds to full speed. The arrangement of the electric steering gear is shown (Fig. 3), where the motor is shown geared by a worm to a quadrant on the rudder post, the motor field is kept constant, and the armature current is varied by passing the resistance arm A, on the left, over the resistance R. The movement of arm A on the bridge causes a corresponding movement of the rudder post and resistance arm A_1. The left-hand arm can, therefore,

* *Electrical World and Engineer*, New York, April 15th.

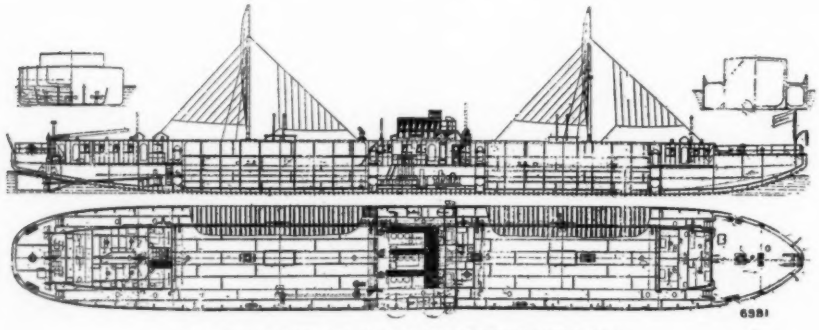


FIG. 1.—ELEVATION AND PLAN OF MOTOR-DRIVEN CARGO BOAT.

be geared to an ordinary steering wheel. The cost of the entire electrical equipment, including the oil engines, was £6,000. The estimates for a pair of compound engines, twin-screw, instead of triple screw, as at present, were about £4,300; a saving of at least £200 per annum must therefore be effected to justify the new system. The actual saving has not yet been determined, but the fact that the thermal efficiency of the oil engines is 35 per cent., against 13 per cent. with steam engines, and that crude petroleum contains about 5,000 calories per lb. and coal about 3,600, shows that one ton of petroleum will do as much work as 3·7 tons of coal. In St. Petersburg a ton of coal costs £1, and a ton of petroleum £1 16s., so that, even allowing for a loss of 20 per cent. due to the conversion of mechanical power into electrical energy and back again into mechanical power, there is considerable advantage in the new method; moreover, the reduction in the weight and bulk of the fuel means greater cargo-carrying capacity: this increase is estimated at 10 per cent. in the case of the *Vandal*. The amount of oil used per round trip of 1,400 miles is about 3,600 gallons. Another vessel is being built and several improvements effected. Twin screws, driven by two 180 B.H.P. Diesel engines, are being used, and both engines and propeller motors will be located aft. To avoid the losses inherent to the conversion of mechanical into electrical energy and back again, clutches are fitted connecting the propeller shafts direct to the oil engines without the intervention of the electrical plant, the latter only being used when nearing port, although all the auxiliary machinery will be electrically driven. It appears that the logical outcome of these experiments will be to demonstrate the suitability of the internal combustion engine for marine purposes, and the advantages of electrically operated auxiliary machinery.

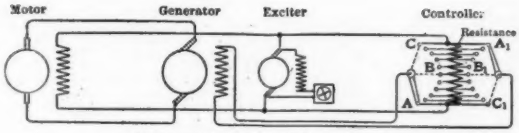


FIG. 2.—MOTOR CONTROL CIRCUITS.

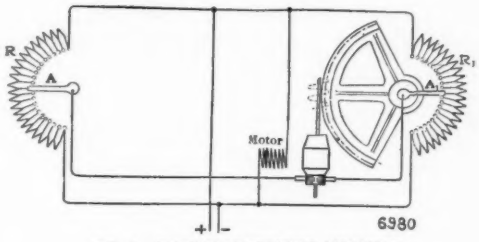


FIG. 3.—DIAGRAM OF STEERING APPARATUS.

Advantages of Motor-Driven Machine Tools.*

G. H. CONDICT.

AMONG the advantages cited were, less loss in distributing power through the shop, as in many American machine shops a loss of 50 per cent. has been recorded in the shafting and belting. With electric driving the losses are somewhat as follows:—From engine shaft to line, 6 per cent.; line loss, 2 per cent.; average motor loss, 17 per cent.; loss between motor shaft and tool shaft, 5 per cent., assuming single pair of gears or chain drive. Total loss engine shaft to tool shaft, 27 per cent. Shafting losses are constant, while with electric distribution the losses are proportional to the power used. Instances were given of a works, entirely equipped with electric driving, where only half the power, as calculated from previous experience with belt driving, was considered necessary. Moreover, even this amount of power was found excessive, as the generating plant was never loaded beyond half its capacity, so that the shop was run on 25 per cent. of the power required with belt driving. With regard to capital cost opinions differed, but, in the opinion of the lecturer, the cost of an electrically-driven factory would be less than with belt driving. Among other advantages would be found greater output, due to the ease with which maximum cutting speed could be maintained, less liability to accidents, as belts are eliminated. A case was cited where a shop had been partially equipped with electric driving, individual motors, the remainder being machines grouped to a line shaft. Owing to a hot bearing on the main shaft twenty-three machinists and their machines were stopped for twenty minutes; such a wholesale stoppage was, the lecturer said, quite impossible in an electrically-driven shop. Owing to the growth of

* Paper read to the National Machine Tool Builders Association at Washington, D.C., U.S.A.

American opinion in favour of independent motor-driven tools, the lecturer said that it was unlikely that shafting and belting would be considered at future meetings of the convention: this tendency was not so much due to a saving in power consequent upon the elimination of shafting as to the greater output per machine owing to the flexibility and convenience of the new method; while, in addition, there was the absence of dirt and non-interference with the lighting, both important but generally under-estimated factors in works organisation.

The Manufacture of Electrical Machinery in Japan.*

THERE are two electrical factories in Japan, both less than ten years old; the largest, the Shibaura Engineering Works, is a branch of the great Mitsui Company of Japan, and covers several acres along the shores of Tokio bay. All the shops are single-storied buildings, but not well planned for economical output. Notwithstanding this, it is said that it can turn out plant 30 per cent. cheaper than American firms can deliver in Japan. Last year the firm turned out 65 direct-current generators, aggregating 1,450 kilowatts; 12 alternate-current generators, aggregating 1,300 kilowatts; 36 direct-current motors, having a total horse power of 600; 60 alternating current motors, totalling to 1,550 h.p; and 910 transformers, having an aggregate capacity of 4,050 kilowatts. The repairs executed under their guarantee is less than 5 per cent. of the total output. The Tokio Tramway Company have three 120 kilowatt motor generators, the alternating-current side operating at 3,000 volts, built at this works. Most of the machine tools are American, though the heavy machinery, shears, punches, steam hammers, &c., were made in Glasgow. It appears that, as a rule, Japanese prefer British-built heavy tools, as they are more reliable than American tools of this class. All the copper wire is made in Japan from copper from Japanese mines; fibre insulation is also native made, but the steel and iron plates and bars are imported from England. So, also, is part of the pig iron, though most of it is from Japanese furnaces. One reason for obtaining iron and steel from England is that, although deliveries from the United States are fully two weeks earlier, Americans cannot compete with the prices quoted by British steel manufacturers. It appears from the article that Americans consider that a great industrial future is before Japan for the following reasons:—The artizans are naturally clever, and, though short in stature, are muscular and robust, the immense and rapidly-growing population in a limited area ensures the abundant supply of cheap labour, the markets of the Far East are at her doors, an abundant supply of coal and copper, and probably also of iron, within her territory. That native talent is equal to the task of building up her industries is apparent from the fact that foreign experts never have been employed at the electrical works. Native designers are paid £15 per month, and artizans from 2*s.* 8*d.* to 3*s.* 1*d.* per day. The Japanese designers are all graduates of European or American technical colleges. Our contemporary urges Americans to take a hand in this industrial development, and, as an instance of the prospects, states that a Japanese company, with a capital of £500,000, has been formed to transmit 10,000 horse-power from a waterfall forty miles from Tokio to that city. In view of the preference for some classes of British machinery, we have no doubt that our manufacturers will not be unrepresented when the contracts for this work are given out.

* *Electrical Review*, New York, April 22nd.

Electromobiles—A Review of the Progress of Such Vehicles, and the Examples of This Class of Automobile at the Automobile Exposition, Berlin.*

THE older lead accumulators gave 9·1 watt hours per pound of cell, and taking a four-seated car weighing 3,300 lbs., four passengers at 880 lbs., a battery having a capacity of 1,700 watt hours, weighing 1,860 lbs., a total weight of 2¼ tons. Such a car had storage capacity for a fifty mile run, assuming a fair average of 110 watt hours per ton mile, a safe figure for ordinary roads. Newer accumulators gave 13 watt hours per pound of cell, so that with the same weight as before the mileage is raised to 74 miles, or if 50 miles is sufficient the battery need only weigh 760 lbs. A still more recent lead cell gives 15½ watt hours per lb., though this increase in capacity is gained by sacrificing the life of the cell, which is reduced from 7,500 to 5,000 miles, 34 per cent.; but the increased depreciation of the battery is more than balanced

* *Elektrotechnische Zeitschrift*, March 2nd, 1905.

by a saving in the maintenance of the tyres, which, owing to the lesser weight of the vehicle, have a longer life. Several recent cars had been fitted with lead-zinc accumulators, giving 22·7 to 32 watt hours per lb. These cells are said to have an unlimited life, and can be charged in half-an-hour. The Jugner cell, a form of the Edison nickel-iron cell, was not considered as an improvement on the other types in which lead was used.

Electric Furnaces—A Note on Dr. Héroult's Paper on this subject.*

THE necessity of a practical furnace in which carbon from the electrodes cannot mix with the steel, and in which the metal can be worked, is enlarged upon. The induction-type furnace, in which the metal acts as the secondary of a transformer,* is excellent for the former reason, but it is said to be impossible to obtain a uniform mixture or rake off the slag easily. In the opinion of Dr. Héroult the simplest form is a hollow and more or less spherical vessel, with some method of heating which will prevent the mixing of carbon with the metal. It is not expected that the electric furnace will effect an immediate revolution in methods of iron and steel manufacture, but the fact that it will produce steel better suited to some purposes than that produced by any other method, will necessitate its adoption. Apart from this, the fact that such furnaces enables us to produce materials which can be produced in no other way, will inevitably lead to its adoption in many industries.

* *Electrical Review*, New York, April 1st.

REVIEW.

Lectures on Iron Founding.—By T. Turner, M.Sc., A.R.S.M., F.I.C.; Professor of Metallurgy in the University of Birmingham. London, C. Griffin & Co. 1904. 3s. 6d. net.

In these lectures delivered to evening audiences of practical men, Professor Turner deals most lucidly with the salient features of iron founding. Commencing with a brief reference to the varieties of iron and steel, the lectures pass in natural sequence from a description of iron ores and their preliminary treatment to the blast furnace and an outline of its reactions. One lecture, the third, is devoted in full to the constituents of cast iron, and forms perhaps the strongest section of the book. The fourth lecture deals generally with foundry practice, including references to cupolas, the influence of remelting and various difficulties lying in the path of the iron founder. The concluding lecture discusses foundry tests, and the structure of cast iron. Such in brief is an outline of an excellent work, which, though modest in size, contains much of practical value.

Taking the book as a whole, its style and treatment are such as to appeal directly to the practical mind. Unnecessary detail is omitted, and the reader is taken through a course of study admitting of immediate application in the iron foundry. The section devoted to moulding is necessarily restricted, and here the terms "dry sand" and "loam" moulding are somewhat confused. For instance, on p. 88:—

"Dry sand moulds are used for special purposes in the foundry, the object generally being the production of a single casting without the cost of providing a pattern." As generally understood dry sand moulding always involves the use of a pattern, and in many iron foundries this method is applied to what in reality is repetition work. Cylinders for example, when moulded in sand from a pattern, are seldom cast "green," the mould being either fully or skin dried, according to its nature.

In discussing common troubles the author says with perfect justice:—

"The iron founder sometimes seems to run on a vein of ill luck" (p. 96). Such ill luck is proverbial in the foundry, and no matter what is done, it always appears to run its course. We venture to think, however, that were every foreman moulder familiar with Professor Turner's Lectures such veins of ill-luck would gradually diminish in frequency.

* *The Engineering Review*, p. 736.

By PERCY LONGMUIR.

The Iron and Steel Institute Annual Meeting.

Blast Furnace Practice.

The Cleaning of Blast Furnace Gas.—In introducing his subject Mr. A. Sahlin emphasises the value of dust free gas for use in gas motors. For stoves, boilers, furnaces, &c., a small quantity of fine buoyant dust is no detriment, as it passes off with the products of combustion through the smoke stack. Therefore a gas containing 0·3 gram per cubic millimetre or less is sufficiently clean for these purposes. On the other hand gas for the gas engine can never be too pure, and the removal of the last trace of dust, though expensive, will pay for itself in longer life and decreased repairs to costly engines. The cleaning of blast furnace gas should take place in three stages. (1) Preliminary dry cleaning, which does not involve extra operating expense; (2) wet cleaning to fit the entire quantity of gas for use in stoves and under boilers, &c.; and (3) special cleaning for purifying part of the gas for power purposes.

The cleaning plant advocated by the author is shown in Fig. 1, which will deal with the entire volume of gas from one furnace. Gas leaves the furnace through four uptakes placed at an angle of 90 degrees. These join into one downcomer which delivers the gas in a tangential direction into a cylindrical dust catcher. From the top of this dust catcher the gas passes through one of two mushroom valves, one of which is in direct connection with the gas main, and is only used in case of repairs to the cleaning plant. The second valve connects the dust catcher with a water seal, from which the gas flows into a Sahlin gas cleaner. From the cleaner it reaches a ventilator, which delivers the sufficiently clean and cooled gas into the bottom of a dryer fitted with cross-bars carrying a column of coarse coke. In passing through this the gas is freed from the bulk of water which may be mechanically carried from the wet cleaning. The dry gas passes through a mushroom valve at the top of the scrubber into the gas main.

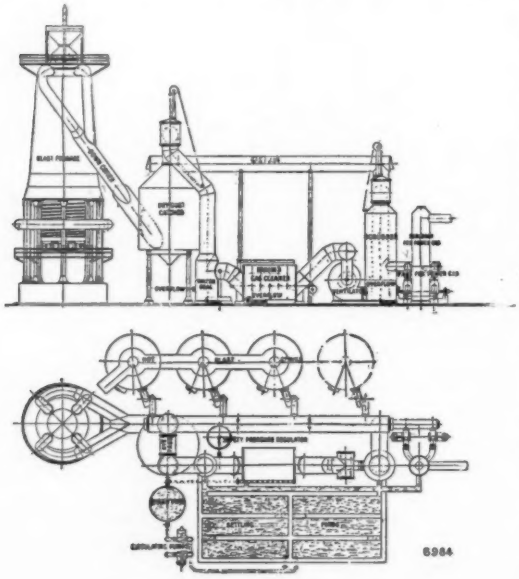


FIG. 1.—CLEANING OF BLAST FURNACE GAS.

Gas for power plant is drawn from the clean gas main, and is passed through one of two electrically driven fans sprayed with water and discharged into a second smaller drier, from which the gas, practically dust free, is passed on to the engines. The size of this final cleaning plant is determined by the quantity of gas required for power. A fan cleaning 10,000 cubic feet per minute, and using 8,000 gallons of spraying water per hour, requires about 65 horse power, and will supply gas engines of from 5,000 to 6,000 horse power. The pumping of spraying water will require about 3 horse power additional.

The Application of Dry Air Blast.—It will be remembered that Mr. Gayley's paper read at the autumn meeting of the Institute created

considerable interest and discussion. Some of the more salient features of this discussion were given in our March issue, the general trend being that the trials were of insufficient duration. Criticisms of this nature are readily answered in the present paper, in which Mr. Gayley gives a record of operations of the Isabella Furnaces from November 1904, to March 1905, inclusive. The average moisture contents of the atmosphere each day and night during this period are given. The monthly average being as follows:—

Month.	Grains of Moisture.			
	In Atmosphere.		In Dry Blast.	
	Day.	Night.	Day.	Night.
November ...	1·99	1·99	1·03	1·01
December ...	1·41	1·47	0·94	0·92
January ...	1·26	1·23	0·67	0·60
February ...	1·19	1·17	0·65	0·54
March ...	2·25	2·25	1·01	0·89

Combining the furnace records into one table, the following monthly comparisons are offered:—

Month.			Average Daily Product. Tons.	Average Coke Consumption. lbs.	Blowing Engines. Revolutions per minute.	Average Temperature. Hot blast.
November.	No. 1 Furnace.	Dry blast ...	447	1,816	96	854° Fahr.
	No. 3 ,,	Natural air ...	386	2,279	111	750° ,,
December.	No. 1 Furnace.	Dry blast ...	455	1,823	96	877° Fahr.
1st—22nd.	No. 3 ,,	Normal blast	400	2,309	111	786° ,,
22nd—31st.	,, ,,	½ dry blast ...	461	2,140	—	—
January.						
1st—10th.	No. 1 Furnace.	Dry blast ...	428	1,825	96	869° Fahr
15th—31st.	,, ,,	Normal blast	414	2,340	111	771° ,,
1st—10th.	No. 3 ,,	Normal blast	410	2,351	111	716° ,,
15th—31st.	,, ,,	Dry blast ...	432	1,811	96	802° ,,
February.	No. 1 Furnace.	Normal blast	424	2,248	111	800° Fahr.
	No. 3 ,,	Dry blast ...	412	1,815	96	784° ,,
March.	No. 1 Furnace.	Normal blast	411	2,274	111	850° Fahr.
	No. 3 ,,	Dry blast ...	405	1,837	96	784° ,,

Turning to the month of December the record of No. 3 furnace when using a small quantity of dry blast is remarkable. The furnace at once began to drive more rapidly, and its burden was increased. There was no deterioration in the grade of metal produced; in fact, it was slightly better as the silicon was higher and the sulphur lower than in the preceding part of the month. On the 10th of the following month the dry blast was changed from No. 1 to No. 3 furnace. Both furnaces were making the same grade of iron for use in the basic open hearth process. No account is taken of the period from the 11th to the 14th inclusive, as this time was occupied in adjusting the dry blast and burden on both furnaces. The reason for this change was a desire to determine the economy on another furnace at a time which represented in that locality nearly the minimum of humidity in the atmosphere. The response to the application of dry blast was prompt and efficient in result, and clearly demonstrated that, even at periods when the humidity of the atmosphere was relatively low, substantial economy in fuel could be obtained. The month of February yielded an exceptionally low moisture content, and the operations on No. 3 furnace were directed towards an economy in coke. The output of No. 3 is less than No. 1, as the former was stopped several times during the month, on account of breakdowns of slag machine and breakouts of iron at the hearth. Notwithstanding the low content of moisture in the normal blast, the furnace supplied with dry blast made, considering the stops, practically as much iron—with a consumption of coke 433 lbs. less per

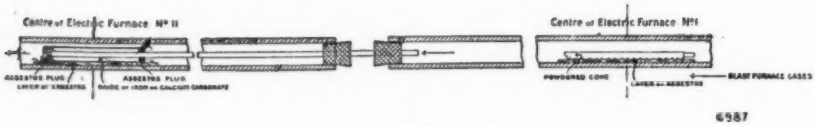


FIG. 2.—SULPHUR IN COKE.

ton of iron—as the furnace supplied with normal blast. As the summer season approaches, the product of the furnace using normal blast will steadily decrease and the fuel increase, while the work of the furnace supplied with dry air will continue practically uniform. It will be noted that in the month of March the product of No. 3 is a little less than No. 1, a feature due to the fact that both furnaces had to be banked owing to floods, and No. 3 was banked nearly one day longer than No. 1.

Sulphur in Coke and its Behaviour in the Blast Furnace.—Professor Wuest and Mr. F. Wolff give at the outset the results of a series of preliminary tests undertaken in order to establish the reactions between the sulphur of coke and various gases at different temperatures. The gases employed include oxygen, hydrogen, water vapour, nitrogen, carbon mon-oxide, and carbon di-oxide, whilst the temperatures range from 500° to 1,000° C. These results lead to the conclusion that similar re-actions occur in the blast furnace, and it is assumed that the sulphur of the coke is volatilised in a similar manner, as it is exposed to the same chemical and thermo-chemical influences as in the experiments. Indeed, from a thermo-chemical point of view, the influence is even greater since the sulphur is subjected to temperatures up to 1,200° or 1,500° C. before reaching the tuyeres. In any case the sulphur of the coke cannot reach the tuyere zone undiminished and unaffected by the heat, as is generally held, but must during the descent of the charge be reacted upon actively by the gases and undergo partial gasification. The sulphur thus set free will, unless it combines again with other substances, pass off with the gases. In order to obtain a definite estimate of the contents of the gases, exhaustive tests were made on a furnace running on forge and basic Bessemer pig iron. These and other results enable the authors to

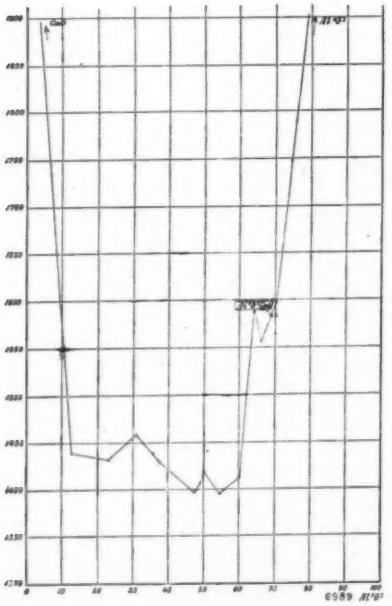


FIG. 3.—FUSIBILITY OF SLAG.

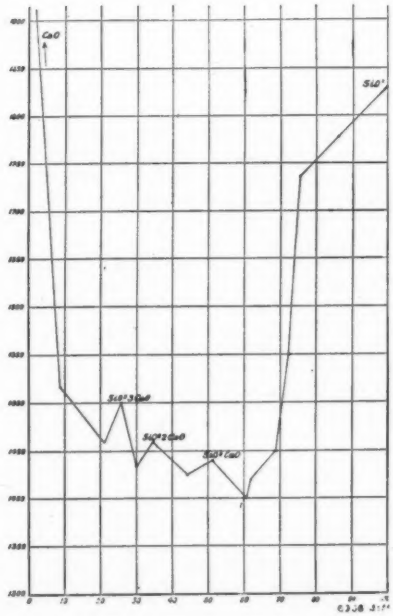


FIG. 4.—FUSIBILITY OF SLAG.

FERRIC OXIDE.

Temperature of the Ignited Coke.	Loss on Ignition.	Sulphur Driven off from Coke.	Volatilised Sulphur in Percentages of the Total Sulphur Content.	Temperature of the Ignited Ferric Oxide.	Sulphur taken up by Ferric Oxide, relative to Original Weight of Coke.	Sulphur taken by Ferric Oxide in Percentages of Total Volatilised Sulphur.
Degrees Cent.	Per cent.	Per cent.	Per cent.	Deg. Cent.	Per cent.	Per cent.
1,000° to 1,050°	23·52	0·6232	44·32	250°	0·3307	53·06
	23·78	0·6933	49·31	500°	0·4439	64·02
	24·66	0·6632	47·17	600°	0·4539	68·33
	24·51	0·8250	58·67	800°	0·5741	69·58
	25·16	0·8211	58·39	900°	0·5585	68·02
	30·43	0·7543	53·64	1,000°	0·4564	62·66

arrive at the following sulphur balance of the blast furnace :

SULPHUR BALANCE.

		Sulphur kilogrammes.
In put.		
2.142	kilogrammes iron ore with 0·123 per cent. sulphur	2·6350
207·3	,, of (a) cinder with 0·121 per cent. sulphur	0·2508
345·6	,, of (b) cinder with 0·113 per cent. sulphur	0·3905
69·1	,, of (c) cinder with 0·078 per cent. sulphur	0·0538
143·0	,, limestone with 0·042 per cent. sulphur	0·0600
1,000·0	,, coke with 0·6899 per cent. sulphur	6·8990
	Total sulphur put in	10·2891
Out put.		
1,000	kilogrammes pig iron with 0·033 per cent. sulphur	0·3300
1,017	,, slag with 0·908 per cent. sulphur	9·2350
315·5	,, light dust in 4,382 cubic metres of gas and with 0·166 per cent. sulphur	0·5238
4,382 cubic metres gas with 0·0034 per cent. sulphur		0·1489
	Total sulphur brought out	10·2377

A further series of experiments, having for an object a more detailed investigation of the conditions under which the sulphur, volatilised by the furnace gases, is absorbed by the charge, *i.e.*, by the ores and limestone, are outlined. In these experiments it is assumed that the sulphur emitted by the coke in the furnace at about 1000° C. at once comes in contact with the charge also at 1000° C. It then ascends, meeting in succession the charges above, and growing constantly cooler as it passes upwards.

The experimental method is shown in Fig. 2, consisting of two electrically heated furnaces, one of them containing coke and the other oxide of iron or lime. Blast furnace gas is passed through the coke heated to the desired temperature, the gaseous current then entering the second furnace which also permits of being heated to any desired temperature. The above table gives results obtained from ferric oxide and it will be noted that at a comparatively low temperature a considerable amount of sulphur is absorbed.

The absorption of sulphur by lime differs from the foregoing, as shown in the following table the amount taken up at 250° and 500° is small, but from 600° it rises rapidly until at 1000° almost the whole of the sulphur has been absorbed.

The authors' results show that :—Contrary to the generally held opinion sulphur in coke does

CARBONATE OF LIME.

Temperature of the Ignited Coke.	Loss on Ignition of the Coke.	Sulphur Driven off from Coke.	Volatilised Sulphur in Percentages of the Total Sulphur Content.	Temperature of the Ignited $Ca\,CO_3$.	Sulphur taken up by the $Ca\,CO_3$ relative to Original Weight of Coke per cent.	Sulphur taken up by the $Ca\,CO_3$ in Percentages of the Total Volatilised Sulphur.
Degrees Cent.	Per cent.	Per cent.	Per cent.	Deg. Cent.	Per cent.	Per cent.
1,000° to 1,050°	29·76	0·8681	61·74	250°	0·0890	10·26
	28·99	0·8428	59·94	500°	0·1406	16·68
	30·56	0·7519	53·47	600°	0·3538	47·05
	22·36	0·5998	42·66	800°	0·3888	68·08
	25·71	0·5753	40·91	900°	0·4933	85·74
	25·77	0·5705	40·57	1,000°	0·5239	91·83

not reach the tuyere level without alteration, but that a large portion of it is previously volatilised by the ascending gases and is then largely absorbed from the gases by the descending charge and in this condition arrives in front of the tuyeres. Up to 800° C. sulphur is chiefly absorbed by oxide of iron from the sulphur-laden gases, whilst from 800° upwards the position is reversed and lime becomes the chief absorbent.

Experiments on the Fusibility of Blast Furnace Slags.—In view of the practical importance of the fusibility of slags, Dr. Boudouard has examined wide series of silicates of lime and alumina; of aluminates of lime and of alumino-calcic-silicates. The method employed was a comparative one and the temperature of softening determined by exposing the slag and a Seger cone to the action of heat. These cones give a range of temperature of from 1010° C. to 1850° C., and between these extremes there are some forty-one cones of intermediate softening temperatures. The slag samples were made of a uniform mixture of the required constituents previously ground to uniform fineness and made up into a cone of similar dimensions to that of the Seger.

Turning to the experimental results, the first series deal with silicates of alumina and a composition of 37·1 per cent. Si. O_2; 62·9 per cent. $Al_2 O_3$ gives a softening temperature of 1890°. This temperature steadily falls with a decrease of alumina, until at 14·5 per cent. it occurs at 1690° C.; at 7·8 per cent. it has risen to 1760° and the softening temperature of pure silica is given as 1830° C. Softening temperatures of a series of lime silicates in which silica varies from 8·9 to 100 per cent. are shown in Fig. 3. In a similar manner aluminates of lime—with alumina varying from 13·2 to 78·5 per cent.—are shown in Fig. 4. In all seven curves of fusibility are given, and as the author justly remarks, these curves give much information as to the constitution of silicates and aluminates. With the silica and alumina series the curve presents one minimum corresponding to the mixture 10 Si. O_2 Al_2 O_3. Fig. 3, silica and lime, gives a curve having three maxima corresponding to

Temperature = 1500° representing Si. O_2 3Ca. O.
" = 1460° " Si. O_2 2Ca. O.
" = 1440° " Si. O_2 Ca. O.

In the case of ternary compounds a study of their fusibility furnishes much of value, and such compounds can be graphically represented by means of the triangular diagram. From his work on the alumino-calcic-silicates the author has plotted a diagram—Fig. 5—showing the isothermal curves of fusibility. This diagram summarises the extent of our knowledge of the fusibility of these silicates, and it further focuses and extends the conclusions previously reached by Åkerman. Using this diagram as a chart the fusion temperature of a given alumino-calcic-silicate can be readily determined.

Finally, by utilising the practical data found in metallurgical treatises, the author has estimated the fusion temperatures of industrial slags derived from various sources:—

Description of Slag.	Percentage Composition.				Temperature.
	Si O_2.	$Al_2 O_3$.	Ca O.*		
Ferro-silicons with 14 per cent. ...	25·0	25·0	50·0		1450°
	35·0	25 0	40·0		1375°
Grey hot blast charcoal pig iron ...	45·0	10 0	45·0		1360°
	65·0	5·0	30 0		1430°
Grey hot blast coke, anthracite and coal pig iron	30·0	20·0	50·0		1420°
	35·0	10·0	55·0		1420°
White pig iron—1. Charcoal... ..f	45·0	10·0	45·0		1360°
	40·0	5·0	55·0		1425°
White iron —2. Coke	30·0	10·0	60·0		1440°
	40·0	5 0	55·0		1425°
			Ca O.	Mn O.	
Spiegeleisen	30·0	10·0	55·0	5·0	1440°
	40·0	10·0	10·0	40·0	1440°

* Under the term "lime" has been included all the oxides other than silica and alumina.

Steel: Its Treatment and Properties.

*Experiments relating to the Effect on Mechanical and other Properties of Iron and its Alloys Produced by Liquid Air Temperatures.**—This important memoir by Mr. Hadfield opens an entirely new field of investigation and discloses some exceedingly remarkable properties possessed by metals and alloys at a temperature of —182° C. For the research over 140 separate

* See also pages 571 and 643, February issue.

combinations have been examined—the number of individual tests reaches the high total of 1,096. Tensile test pieces were 0·1 8 in. diameter and the elongations measured on a length of 2 in.; the tests were carried to completion with the specimen and its holders entirely immersed in liquid air—that is, each bar was broken at a temperature of —182° C. Many duplicate tests were made, and with the exception of one or two slight differences, the results were in very close agreement.

Generally the effect of this low temperature on iron and its alloys is to considerably increase the maximum stress and to reduce or eliminate ductility. A series of irons, including one of high purity, viz., S. C. I., with only 0·045 per cent. C., all show this remarkable decrease of ductility. These features of high tenacity and low ductility are common to nearly all of the many alloys tested. Further, the effect only holds during the continuation of the low temperature, and on returning to normal temperature normal properties are again shown.

An important point with iron lies in the fact that the increase in tenacity is gradual and progresses with a fall in temperature. This is illustrated in Fig. 6, plotted from results obtained by testing samples of S. C. I. at temperatures of —18°.—80°.—100° and —193°C. The curve clearly shows that gradual decrease in temperature is accompanied by gradual increase of tenacity, and that there is no *critical point*. The dotted portion is made on the assumption that the curve would continue to rise proportionately if the temperature were reduced to absolute zero, in which case the tenacity of pure iron would be 70 tons per sq. in.

Samples of S. C. I. yield by the Brinell test at normal temperature a hardness number of 90, when tested at —182° the hardness rises to 266. Specimens of the same iron quenched in liquid air from a temperature of 950° C., and subsequently tested at normal temperature, show no decrease, but rather an increase, of ductility.

Carbon steels when tested in liquid air behave similarly to the irons, that is, ductility practically vanishes and tenacity increases. Results obtained at normal and low temperatures are shown in Fig. 7, this diagram also

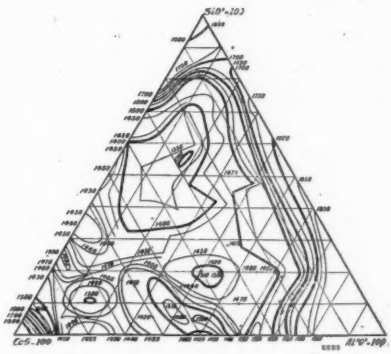


FIG. 5.—FUSIBILITY OF SLAG.

including the analyses of the steels. Singularly enough, carbon steels quenched in liquid air from high initial temperatures are not hardened.

Dual alloys with iron as chief constituent behave very similarly to the foregoing, but in the case of iron and nickel an important exception is noted. The results show that the brittleness induced in iron by low temperatures is very considerably modified by the presence of nickel.

Triple alloys with iron as chief constituent present many interesting features, but on the whole these alloys are embrittled by low temperatures in a manner analogous to the irons and steels. In the case of one alloy containing 1·25 per cent. C., 2·01 per cent. Mn., and 1·39 per cent. Cu. a remarkable rise in tenacity is shown, whilst the elongation remained unaffected by the low temperature, copper apparently neutralising the embrittling effect of manganese at —182° C.

The crux of the paper is, however, found in the remarkable behaviour of triple alloys of iron, manganese and nickel, and one of these alloys represented the first specimen met with in which the ductility remained comparatively high at —182° C. The following figures are of much moment, in that they illustrate the effect

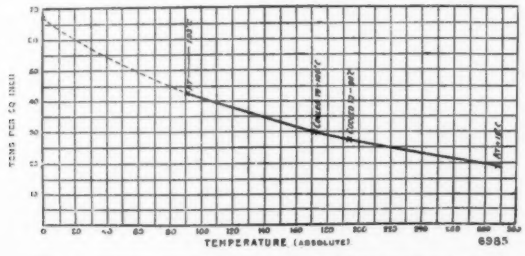


FIG. 6.—COOLING CURVE OF THE S.C.I. (SWEDISH CHARCOAL IRON).

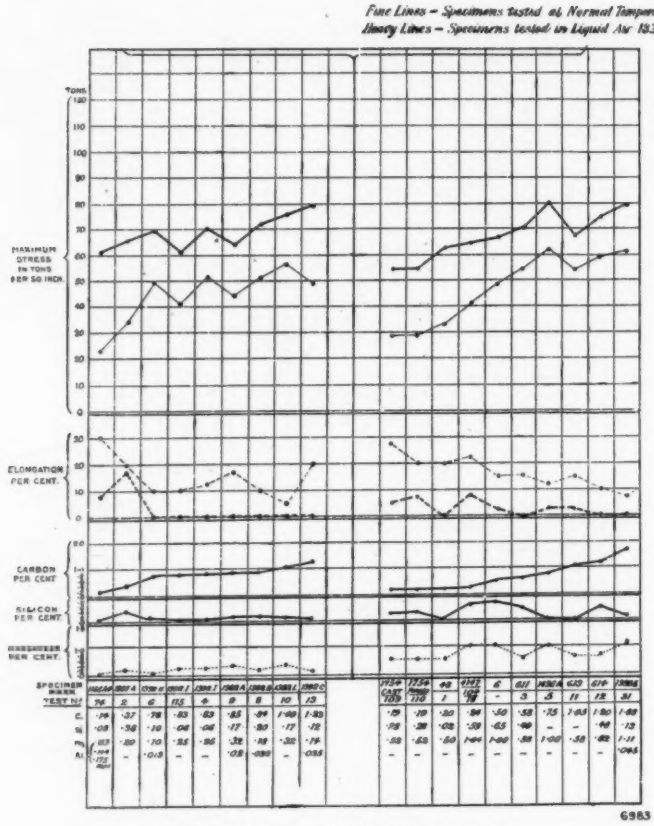

Fine Lines = Specimens tested at Normal Temperature.
Heavy Lines = Specimens tested in Liquid Air 182° C.
MAXIMUM STRESS IN TONS PER SQ INCH
ELONGATION PER CENT.
CARBON PER CENT
SILICON PER CENT.
NICKEL PER CENT.
6983

FIG. 7.—EFFECT OF LOW TEMPERATURE ON IRON.

of an ascending nickel content in brittleness until finally an actual *rise* in ductility at —182° :—

work conclusively shows that pure iron is—at low temperatures—rendered into a distinctly brittle metal, yet the last alloy contains 68 per

Analyses.			Normal Temperatures.		Liquid Air Temperatures.	
C.	Mn.	Ni.	Max. Stress Tons per sq. in.	Elongation. Per cent. on 2 in.	Max. Stress. Tons, per sq. in.	Elongation. Per cent. on 2 in.
0·60	5·04	14·55	59	70	72	25
1·00	6·05	17·91	49	57	75	42
1·18	6·05	24·30	51	60	84	67

A maximum stress of 84 tons associated with an extension of 67 per cent. forms a phenomenal alloy, and the fact that these values were obtained from an alloy tested at —182° increases their exceptional character. The whole of the cent. iron, and at —182° has a higher ductility than at normal temperature. In other words, this alloy is at —182° far more ductile than the very best type of ductile iron and its tensile strength is three times greater.

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